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A SUBMISSION TO THE TREASURY BOARD OF CANADA

IN SUPPORT OF A PROPOSAL
FOR

SCIENTIFIC STUDIES TO BE CONDUCTED IN RESPONSE TO AN OIL SPILL IN THE BEAUFORT SEA

PREPARED BY

DEPARTMENT OF FISHERIES AND THE ENVIRONMENT
WESTERN AND NORTHERN REGIONAL BOARD

FISHERIES AND OCEANS
WINNIPEG

FEBRUARY 1979

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TREASURY BOARD SUBMISSION

Subject: A proposal for scientific studies to be undertaken in response to oil spills in the Beaufort Sea.

Proposal: To prepare for and to implement a scientific plan to maximize the research advantage afforded by an oil spill of opportunity, especially with respect to improving the predictive capability for future situations and to assess the environmental damage resulting from an oil spill in an Arctic marine environment.

Preparation, maintenance, and updating of the Scientific Response Plan will be the responsibility of Fisheries and Oceans, Winnipeg. Responsibility for the implementation of the Scientific Response Plan will be undertaken jointly by Fisheries and Oceans, Winnipeg and Sidney B.C. (Institute of Ocean Sciences).

Cost: To prepare the Scientific Response Plan (1979-80 FY)

$363,000

To implement the Scientific Response Plan (as needed)

$1,168,000

Chargeable to: Department of Fisheries and Oceans

Vote 5, Fisheries and Oceans operating expenditures.

Remarks: 1) Exploratory drilling for oil and gas under the continental shelf of the Beaufort Sea has indicated that this area could be a major hydrocarbon repository. With an on-going

exploration, there already exists a low probability that a major oil spill will occur from an oil well blowout or a fuel supply operation. Subsequent phases of commercial oil production and transportation, concurrent with further exploratory and delineation drilling, will increase the odds to a high probability that at least one major oil spill would occur from a well, a tanker or barge accident, or a sub-sea pipeline rupture.

2) On the basis of small scale experiments and baseline studies conducted through the Beaufort Sea Study Project and the Arctic Marine Oilspill Program, scientists have made predictions on the possible fates and effects of an oilspill in the Beaufort Sea. The accuracy of these predictions is unknown as is the time required for an Arctic marine area to recover from an oilspill. The most acceptable method of ascertaining the behaviour fate and environmental impact of oilspills is through the monitoring of accidental spills.

3) In view of the increasing level of petroleum exploration activity in Canada's frontier areas, it is important that adequate monitoring studies be carried out during and after any major spill in Arctic waters and especially following the first such oilspill.

4) The Beaufort Sea Scientific Response Plan is a multi-disciple, inter-department plan involving the Department of Fisheries and Oceans, the Department of the Environment (Canadian Wildlife Service, Atmospheric Environment Service), the Department of Energy, Mines and Resources (Canada Centre for Remote Sensing, Geological Survey of Canada) and the Government of the Northwest Territories. Project management for the preparation and maintenance of the plan will come from Fisheries and Oceans, Freshwater Institute, Winnipeg while project management for the implementation of the scientific response plan will come jointly from Fisheries and Oceans, Winnipeg and the Institute of Ocean Sciences, Sidney, B.C.

5) Funding for the Scientific Response Plan is requested in two phases. Phase I is for funds to improve the scientific response capability through the purchase and stockpiling of additional equipment and supplies. Phase II is a guarantee that in the event of an oil spill in the Beaufort Sea funding will be made available to the participating agencies to implement the Scientific Response Plan.

6) Although the scientific response plan has been designed primarily to cope with an oil spill in the Beaufort Sea, there are many facets of the plan that could be adapted to cope with the study of an oil spill in any of the coastal zones of Canada. The purchase of spill tracking buoys, current

meters and in particular a remote sensing system for the Canada Centre for Remote Sensing will aid the improvement of Canadian spill response capabilities.

APPENDIX 1

AN OVERVIEW OF THE BEAUFORT SEA SCIENTIFIC RESPONSE PLAN

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TABLE OF CONTENTS

APPENDIX 1

AN OVERVIEW OF THE BEAUFORT SEA SCIENTIFIC RESPONSE PLAN

Introduction	1
Objectives	3
Summary of Scientific Studies	4
Project Management	10
Interface of the Scientific Response Plan with Oil Spill Contingency (Operational Countermeasures) Plans	12
Interface of the Scientific Response Plan with Ongoing Government Programs	14
Capital Expenditures	15
Towards a National Scientific Response Plan	19

LIST OF TABLES, FIGURES

TABLE

1	Priorities of Studies and Relationships Between Studies	7
2	Oil Spill Conditions Necessary for the Implementation of the Studies	8
3	Timing and Major Logistical Requirements of Scientific Studies	9
4	Funding Required to Prepare and to Implement the Beaufort Sea Scientific Response Plan	11

FIGURE

1	Study Area for the Beaufort Sea Oil Spill Scientific Response Plan	6

BEAUFORT SEA SCIENTIFIC RESPONSE PLAN

OVERVIEW

Introduction

Exploratory drilling for hydrocarbons under the continental shelf of the Beaufort Sea has indicated that this area could be a major oil and gas respository. This prospect is encouraging for Canada's future energy needs, but this optimsim must be tempered by the associated risks of oil spills and their potential impacts. With on-going exploration there already exists a low probability that a major oil spill will occur from an oil well blowout or ship operations in the area. Indeed, there have already been two uncontrolled waterflows from wells drilled by Canadian Marine Drilling Ltd. (Canmar). Had these been oil instead of water, an environmental crisis may have developed. In addition the recent spills of 208 tonnes (230 tons) of diesel fuel from the Canadian Coast Guard icebreaker "John A. MacDonald", while under charter to Canmar and of an undetermined amount of fuel oil from the grounding of a Canmar supply vessel have graphically illustrated the potential for large-scale accidental spills. If the hydrocarbon potential of the area is proven in the exploratory drilling program, subsequent phases of commercial oil production and transportation, concurrent with further exploratory and delineation drilling will increase the odds to a high probability that at least one major oil spill could occur from a well, a tanker or barge accident, or from a sub-sea pipeline. Canmar is currently in process of constructing an Arctic class 4 icebreaker and is proposing the development of an Arctic class 10 icebreaker or Arctic Marine Locomotive (AML). In a recent submission to the Department of Finance, Canmar suggested that an Arctic class 10 AML icebreaker could be used to

accompany 165,000 DWT Arctic class oil tankers from the Beaufort Sea through the Northwest Passage to Canadian east coast ports. Similarly, Standard Oil Ltd. has stated that if suitable icebreaker support is available 250,000 DWT ice-breaking oil tankers are technically and economically feasible.

On the basis of small-scale experiments and baseline studies conducted under the auspices of the Beaufort Sea Study Project, the Eastern Arctic Marine Environmental Study (EAMES), and the Arctic Marine Oilspill Program (AMOP), scientists have made predictions as to the possible fates and effects of an oil spill in the Beaufort Sea and other Arctic marine areas. The accuracy of these predictions is unknown, as is the time required for an Arctic marine area to recover from the impacts of an oil spill.

Although some of the many questions concerning the fate and effects of oil spills in an Arctic marine environment can be answered through the use of experimental oil spills, as proposed by AMOP, the most acceptable method of ascertaining the overall fate and environmental impacts of an oil spill is through the monitoring of accidental spills. In view of the amount of hydrocarbon exploration production and transportation activity expected to occur in the Beaufort Sea and in other Arctic marine frontier areas, and the lack of information on the environmental consequences and significance of oil spills in Arctic waters, it is important that adequate monitoring studies be undertaken during and after any major spill in Arctic waters, and especially after the first such spill.

In order to develop a useful assessment of the environmental impacts of an oil spill, many types of site-specific information must be obtained, a number of which can only be obtained at the time of the spill. Because

scientists are generally unprepared in terms of both pre-planned studies and availability of equipment, some or all of this information is frequently not collected. It has been demonstrated on previous occassions (Arrow spill, 1970; Argo Merchant spill, 1976; Ekofisk Bravo platform spill, 1977; Amoco Cadiz spill, 1978) that an ad hoc approach to studies at the site of a major spill results both in major gaps in the scientific information gathered and in inefficient utilization of available logistic resources. The need for preplanned scientific response programs has been widely recognized. In the United States, the National Oceanic and Atmospheric Administration is currently developing regional response plans. It should be noted that an early draft of the Beaufort Sea Scientific Response Plan was used as the basis for the development of a scientific response plan for Alaska. Similarly, an early draft of the Beaufort Sea Scientific Response Plan was enthusiastically received by the International Council for the Exploration of the Sea and a working group was convened to develop a similar response plan.

Objectives

The Beaufort Sea Scientific Response Plan consists of some 28 integrated studies that will be conducted in the event of a significant oil spill in the Beaufort Sea.

The general objectives of studies included in the scientific response plan are the following:

1) to assess the fate and immediate impacts of an oil spill in an Arctic marine environment
2) to obtain information during and/or immediately after an oil spill

that is important to the long-term assessments both of the chronic effects of the spill and of the recovery rates from the spill; and,

3) to obtain information that will increase predictive capabilities with respect to the behaviour and fate of oil that is spilled both specifically in the Beaufort Sea and generally in Arctic marine environments.

The specific objectives for each individual study are given in Appendix 2 "Description of Studies".

The delineation of studies for the scientific response plan has been done under two basic guidelines. The first guideline is that the response plan consists of short term studies of no longer than 12 months in duration. Although some studies of longer duration will be necessary to monitor the chronic impacts of a spill, a special supplementary submission for funding will be prepared if and when these long-term studies are deemed necessary. The second guideline has been that the role of the scientific response plan will be to monitor an oil spill and the associated impacts. Studies to evaluate the effectiveness of oil spill countermeasure activities have not been included as part of this submission.

Summary of Scientific Studies

The Beaufort Sea Scientific Response Plan has been developed to cope with the worst possible case of an oil spill. In the event of a spill of lesser magnitude, the scientific response could be limited to those studes applicable to the situation. At the current stage of the exploration process, an oil well blowout (particularly in the transition ice zone) is predicted to be the most serious type of an oil spill in that it could release

large quantities of oil over an extended period of time before it was brought under control and could affect extensive areas of the Beaufort Sea and adjacent coastlines of both Canada and the State of Alaska (Milne and Smiley, 1976). However, should commercial quantities of oil be discovered beneath the Beaufort Sea, spills could originate from production platform accidents (e.g. Ekofisk Platform Bravo, North Sea, 1977) from sub-sea pipeline ruptures or from tanker accidents.

The area of concern consists of the continental shelf area of the Beaufort Sea from the Yukon-Alaska border eastward to Cape Bathurst plus the western edge of the Amundsen Gulf (fig. 1).

A list of the 28 studies, the priorities for implementation and the relationships between each of the studies is given in Table 1. The studies have been assigned first, second, third or fourth level priority. First-level priority studies are those studies that are prerequisites for the successful implementation of any subsequent part of the scientific response plan. Second-level studies are those studies that will adequately and convincingly assess the immediate fate and impacts of a spill or that are critical in establishing a baseline for long-term studies on the rate of recovery of oiled areas. Third-level studies will provide useful information as to the fate and effects of a spill but the implementation of these may be limited by the availability of suitable logistical arrangements (i.e. sampling platforms). Fourth-level studies are even further constrained by logistical requirements and so have been given a lower priority.

Conditions under which each of the studies can be implemented are given in Table 2. The timing of and major logistical requirements for each study are presented in Table 3.

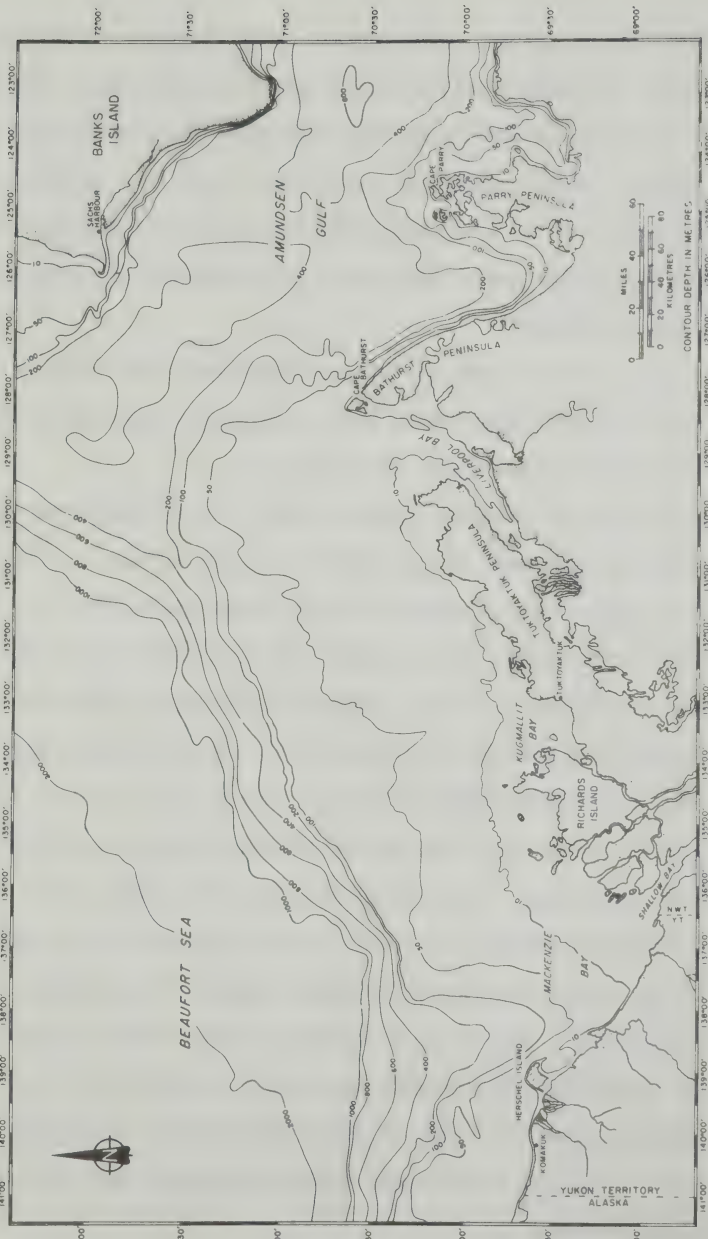

Figure 1. Study area for the Beaufort Sea Oil Spill Scientific Response Plan.

Table 1. Priorities of Studies and Relationships Between Studies.

STUDY	Priority Level	Prerequisite Studies [1]	Necessary Complementary Studies [2]	Optional Complementary Studies [3]	Dependent Studies [4]	Pre-Spill Studies Required	Long-Term Studies Required
1 Monitoring the Movement of Oil							
A Aerial Reconnaissance	1	-	1B	2A	*	-	-
B Radio Tracking of Surface Oil	1	-	1A	2A	1A,2A,4C, 4D,4E	-	-
C Radio Tracking of Oil Under Ice	1	-		1A,2C,2D			
2 Factors Affecting Movement of Oil							
A Effects of Surface Currents and Winds	2	-	1A,1B	-	1A,1B,4C	Desirable	-
B Effects of Subsurface Currents	3	-	1A,4A		4A,8		
C Effects of Under-Ice Currents	3	-	1C,2D,4A		1C,2D,4A, 7, 8		
D Effects of Under-Ice Topography	2	1A	1C,2C		1C,2C,7,9A, 10B		
3 Measurement of the Plume Profile	4			1A			
4 Deposition and Decomposition of Oil							
A Oil in the Water Column	3		2B,2C	1A,1C,4C,4D	2B,2C,4C, 4D,4E,7,8		
B Oil in the Coastal Zone	2	1A		4D,4E	4C,4D,6,9B, 9D		Necessary
C Oil in Sediment-Laden Waters	3	1A	4B	1B,2A,4A	4A,6		Necessary
D Chemical Weathering of Oil	2		1A,1B,1C	4A,4B,4E	4A,4B,4E,6,7		
E Microbial Decomposition of Oil	2		1A,1B	4A,4D	4B,4D,6		Necessary
5 Toxicity of Spilled Oil	2				6, 7, 8	Desirable	
6 Effects of Oil on Coastal Ecosystems	2	1A	4B	4C,4D,4E,5	8,9B,13		Necessary
7 Effects on Under-Ice Flora & Fauna	2	1C	2D	2C,4A,4D,5	8, 13		
8 Effects on Plankton and Fish Populations	3	1A, 1C	2B,2C,4A,5	6, 7	13	Desirable	Possible
9 Effects of Oil on Water Birds							
A Mortality During Spring Migration	2	1A, 1C	2D	-	13	-	-
B Mortality to Moulting Sea Ducks	2	1A	-	4B, 6	13	-	-
C Mortality in Offshore Open Waters	4	1A	-	-	13	-	-
D Effects of Storm Surges on Birds	2	1A	4B	-	13	-	Possible
10 Effects of Oil on Seals							
A Spring Distribution & Numbers	2	1A,1C	-	10C, 11	10C,11,13	Necessary	Possible
B Effects in the Fast Ice Zone	2	1A	2D	11	11,13	-	-
C Effects in the Transition Zone	3	1A,1C	-	10A, 11	10A,11,13	-	-
11 Effects of Oil on Polar Bears	2	1A,1C	-	10A,10B,10C	10A,10B,10C, 13	Necessary	Possible
12 Effects of Oil on Whales							
A Effects on Whales During Spring	2	1A,1C	-	-	12B, 13	-	-
B Effects on Whales During Summer	2	1A,12A	-	-	13	-	-
13 Effects on Human Utilization of Wildlife	2	-	10A,10B,10C,11 12A,12B	6,7,8,9A,9B, 9C,9D	-	-	Possible

[1] Studies that must be conducted to determine the need for the given study.

[2] Studies that must be conducted in conjunction with the given study to ensure meaningful results.

[3] Studies whose results would assist in (but are not critical to) the interpretation of the results of the given study.

[4] Studies that depend on or would be assisted by the results of the given study.

* 1B,1C,2A,2B,2D,3,4A,4B,4C,4E,6,8,9A,9B,9C,9D,10A,10B,10C,11,12A,12B.

\+ 2C,2D,4A,4D,7,8,9A,10A,10C,11,12A.

Table 2. Oil Spill Conditions[1] Necessary for the Implementation of the Studies.

		Open Water			Ice Cover	
	STUDY	Offshore	River plume	Onshore	Transition	Fast ice
1	Monitoring the Movement of Oil					
	A Aerial Reconnaissance	A	A	A	A	A
	B Radio Tracking of Surface Oil	A	A	A		
	C Radio Tracking of Oil Under Ice				A	A[2]
2	Factors Affecting the Movement of Oil					
	A Effects of Surface Currents and Wind	A	A			
	B Effects of Subsurface Currents	L	L			
	C Effects of Under Ice Currents				L	L
	D Effects of Under Ice Topography				L	L
3	Monitoring of the Blowout Plume	L[3]	L[3]		L[3]	L[3]
4	Deposition and Decomposition of Oil					
	A Oil in the Water Column	L	L		L	L
	B Oil in the Coastal Zone			A		
	C Oil in Sediment-Laden Waters		A			
	D Chemical Weathering of Oil	A	A	A	A	A
	E Microbial Decomposition of Oil	A	A	A		
5	Toxicity of Spilled Oil	L	L	L	L	L
6	Effects of Oil on Coastal Ecosystems			L		
7	Effects on Under Ice Flora and Fauna				L	L
8	Effects on Plankton and Fish Populations	L			L	L
9	Effects of Oil on Water Birds					
	A Mortality During Spring Migration				A	A
	B Mortality of Moulting Sea Ducks			A		
	C Mortality in Offshore Open Waters	L				
	D Effects of Storm Surges on Birds			L[4]		
10	Effects of Oil on Seals					
	A Spring Distribution and Numbers				L	L
	B Effects in the Fast Ice Zone					L
	C Effects in the Transition Zone				L	
11	Effects of Oil on Polar Bears				L	L
12	Effects of Oil on Whales					
	A Effects on Whales During Spring				L	
	B Effects on Whales During Summer		L			
13	Effects on Human Utilization of Wildlife	L	L	L	L	L

[1] A any spill for which the response plan is to be implemented
L large spill

[2] Optional

[3] Blowout only

[4] Storm surge inland.

Table 3. Timing[1] and Major Logistical Requirements of Scientific Studies.

STUDY NUMBER[2]	MAJOR LOGISTICAL REQUIREMENTS					TIMING
	DEEP WATER VESSEL	NEAR SHORE VESSEL	FIXED WING AIRCRAFT	HELICOPTER	CCRS AIRCRAFT	Jly Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun
1A			X	X	X	Reduced Intensity
1B			X			
1C				X		
2						
2A			X			
2B	X					
2C				X		
2D					X	
3	X					
4A	X			X		
4B		X		X	X	
4C			X			
4D	X			X		
4E	X	X		X		
5						
6				X		N/A[3] Reduced Intensity
7				X		
8	X			X		
9A			X			
9B			X			
9C			X			
9D				X		
10A			X			
10B				X		
10C				X		
11				X		
12A			X			
12B			X			
13						

[1] Assuming open-water period mid-July to late October, ice cover mid-November to end of June.

[2] See Table 1 for study names.

[3] N/A - Not applicable.

The funding necessary to prepare and to implement each of the studies is summarized in Table 4. Funds necessary to prepare a study are those expenditures that should be made in advance of any spill in order to purchase and stockpile necessary scientific equipment. Funding for the implementation of each study is a realistic estimate based on the best available information. However, many factors such as logistic support and accommodation cannot be determined until the time of the spill.

With few exceptions, the studies have been presented as single units, each with separate funding, logistical and personnel requirements. This has been done so that each study can be evaluated separately. In the event that the response plan is implemented it will be the responsibility of the Program Manager to ensure that studies are conducted cooperatively with optimum utilization of available personnel, resources and logistical support.

Project Management

Project Management for the Beaufort Sea Scientific Response Plan will come from the Environmental Secretariat, Fisheries and Oceans, Winnipeg. Mr. Dennis G. Wright, Environmental Coordinator, has been appointed to fill this role by the Western and Northern Regional Board of the Department of Fisheries and the Environment. The Project Manager has the responsibility to ensure that the response plan is maintained in a state of readiness, to be implemented at any time; that equipment is maintained in an operational state; that the Response Plan is maintained commensurate with current impact assessment and surveillance techniques. Should an incident of sufficient magnitude to warrant the activation of the response plan occur, the Project Manager would coordinate the implementation of the studies and would act as

Table 4. Funding Required to Prepare and to Implement the Beaufort Sea Scientific Response Plan.

PRIORITY		STUDY	FUNDS REQUIRED To Prepare	To Implement
1	1A	Remote Sensing/Aerial Reconnaissance	174,000	353,000 *
	1B	Radio Tracking of Surface Oil	24,000	-
	1C	Radio Tracking of Oil Under Ice	65,000	21,000 *
		Priority 1 - Sub Total	263,000	374,000 *
2	2A	Effects of Surface Currents & Winds	24,000	15,000
	2D	Effects of Under Ice Topography	-	-
	4B	Oil in the Coastal Zone	2,000	38,000
	4D	Chemical Weathering of Oil	3,000	20,400
	4E	Microbial Decomposition of Oil	-	6,500
	5	Toxicity of Spilled Oil	9,000	32,000
	6	Effects of Oil on Coastal Ecosystems	20,000	74,000
	7	Effects of Oil on Under-Ice Flora & Fauna	8,000	70,000
	9A	Bird Mortality During Spring Migration	-	55,000
	9B	Mortality to Moulting Sea Ducks	-	33,000
	9D	Effects of Storm Surges on Birds	-	6,600
	10A	Spring Distribution & Numbers of Seals	-	25,000
	10B	Effects on Seals in the Fast Ice Zone	-	87,500
	11	Effects of Oil on Polar Bears	-	66,000
	12A	Effects on Whales During Spring	-	4,000
	12B	Effects on Whales During Summer	-	40,000
	13	Effects on Human Utilization of Wildlife	-	No estimate
		Priority 2 - Sub Total	66,000	573,000
3	2B	Effects of Sub-surface Currents	22,500	16,000
	2C	Effects of Under-Ice Currents	-	31,000
	4A	Oil in the Water Column	10,000	46,000
	4C	Oil in Sediment-Laden Waters	500	15,000
	8	Effects of Oil on Plankton & Fish Populations	1,000	15,000
	10C	Effects on Seals in the Transition Zone	-	58,000
		Priority 3 - Sub Total	34,000	181,000
4	3	Measurement of Plume Profile	-	16,000
	9C	Mortality of Birds in Offshore Open Waters	-	24,000
		Priority 4 - Sub Total	-	40,000
		TOTAL	363,000	1,168,000
TOTAL TO PREPARE AND IMPLEMENT			1,531,000	

* Implementation costs to be recovered from the polluter.

a liasion between the scientific response plan and the industry and government contingency (operational countermeasures) plans.

Interface of the Scientific Response Plan With Oil Spill Contingency (Operational Countermeasures) Plans.

As part of the operational requirements for hydrocarbon exploration permits, industry has had to develop contingency plans to cope with the containment and recovery of any accidental spillage of oil. A contingency plan to provide an operational response to a major oil spill in the Beaufort Sea has been developed by the Government of Canada to supplement the countermeasures plans prepared by the oil industry. This plan would be implemented should the industry plan prove to be ineffective. The Beaufort Sea Scientific Response Plan has been developed to be separate from, yet complementary to the operational countermeasures plans of both industry and government. Formal interface of the Scientific Response Plan and the Government Contingency Plan will be provided by the Project Manager who will sit as a member of the Spill Observation Team and of the Advisory Support Team to the on-scene-commander.

The Spill Observation Team has the responsibility for observing the industry response to an oil spill and making recommendation on the need for activating the government contingency plan. Through this mechanism, the Project Manager would be able to observe the situation and make recommendation to the senior management of the Departments of Fisheries and Oceans and the Environment that even though the spill may not be of sufficient magnitude to warrant the implementation of the government contingency plan, it still may be scientifically advantageous to implement all or portions of

the Scientific Response Plan.

From Table 1 it can be seen that aerial reconnaissance/remote sensing and oil trajectory plotting (studies 1a,b,c) are integral prerequisites to the successful implementation of all of the other scientific response studies. Similarly, these studies are of vital importance to operational countermeasures plans. At present, the equipment requirements necessary to implement these tanks are not available through the government contingency plans. Funding for the purchase of this equipment is sought through this submission. Because of the operational aspects of these studies, the equipment would be put at the disposal of the on-scene-commander who would bear responsibility for implementation of these studies.

This ensures:

a) that necessary equipment, vital to the successful implementation of operational countermeasures and scientific response studies will be available;

b) that there will be no overlap of operational functions between the contingency plan and the scientific response plan;

c) that the "polluter pays" principle will apply and industry (the polluter in this case) will bear the costs of operational projects as government countermeasures activities are cost recoverable from industry under the terms and conditions of the drilling permits.

It is understood that where there is a conflict between the Scientific Response Plan and the operational countermeasures plans for available logistical and support services or if scientific research studies are in any way interfering with countermeasures activities, the needs of the Scientific Response Plan will be secondary to those of the contingency plans.

Interface of the Scientific Response Plan with On-going Government Programs

The Government of Canada has invested considerable funds ($3.2 M) in support of the Arctic Marine Oilspill Program (AMOP) under the direction of the Department of Fisheries and the Environment, Environmental Protection Service. The objectives of this program are to develop appropriate technology and expertise to combat oil spills in Arctic waters. In addition, some government funds are being used to support the Eastern Arctic Marine Environmental Study (EAMES) coordinated by industry and the Department of Indian & Northern Affairs and the Offshore Labrador Survey (OLABS) coordinated by industry and the Department of Energy, Mines and Resources. These programs are adding greatly to Canada's understanding of Arctic and sub-Arctic marine ecosystems and the potential impacts of hydrocarbon exploration on these systems.

The AMOP project has made significant studies in the development of new technology and techniques to counteract oil spills in ice-infested waters. It is the responsibility of industry and government contingency plans to utilize the results of the Arctic Marine Oilspill Program to the best advantage.

The Beaufort Sea Scientific Response Plan has been able to draw extensively on the AMOP program for specialized equipment. The remote sensor package recommended for use by the Canada Centre for Remote Sensing in Study 1A was tested under the auspices of AMOP. The surface spill tracking buoys described in study 1B were evaluated through a contract to AMOP. The combination of a macro/micro ice tracking system described in Study 1C was also a recommendation of the AMOP program.

The Arctic Marine Oilspill Program is planning to undertake a series

of experimental oil spills to test equipment and procedures and to study some of the fates and effects of oil in an Arctic marine environment. The Beaufort Sea Scientific Response Plan and the AMOP experimental oil spill projects will be complementary. It may be possible to eliminate some studies from the Scientific Response Plan if it is concluded that sufficient information has been obtained through an experimental oil spill. Similarly it may be of greater scientific value to undertake some of the Scientific Response studies such as Study 4D. Chemical Weathering of Oil, Study 4E, Microbial Decomposition of Oil, Study 5, Toxicity of Spilled Oil and Study 7 Effects on Under-Ice Flora and Fauna under a controlled experimental oil spill situation than during a spill of opportunity. Conversely, an uncontrolled spill might reduce the need to undertake an experimental oil spill. The Program Managers of both programs will work together to ensure that there is no duplication of effort and that resources allocated to both programs are used to the best scientific advantage.

Similarly, it may be possible to delete studies from the Scientific Response Plan if it is concluded that sufficient data has been obtained under the auspices of the EAMES or the OLABS projects. The Program Manager will be responsible for examining all results and determining the need for additional studies under the Scientific Response Plan.

Capital Expenditures

Capital expenditure requirements are described in detail in Appendix 2 "Beaufort Sea Scientific Response Plan - Description of Studies".

Of prime importance to both the Scientific Response Plan and the Contingency Plan is the need to know the location, rate and direction of

movement, extent and fate of oil both under open water and ice conditions. Highly specialized equipment is needed for these tasks. The Canada Centre for Remote Sensing (CCRS) has agreed to undertake the task of remote sensing of a major oil spill. Although the CCRS aircraft are equipped with a wide range of sophisticated remote sensors, data is currently recorded on magnetic tape and photographic film and must be brought to Ottawa for processing. At present only the laser fluorosensor has a real-time display. The requirements of the Scientific Response Plan and the Contingency Plan can be most completely served if sensor data are available on a real-time basis or at least as soon as the aircraft lands. CCRS propose to construct a Real Time Display Interface System for the infra-red and multi-spectoral line scanners so that data would be displayed in-flight as a real-time tactical aid and also recorded, with annotation, on videotape so that it could be played back immediately on landing. The data would also be recorded in its present manner for more sophisticated processing and interpretation at a later time. A real-time display interface system would be composed of the following modules:

Aircraft equipment	Real Time Display Interface
	High Resolution TV Monitor
	High Resolution Videotape Recorder
Ground Playback Equipment	High Resolution TV Monitor
	High Resolution Videotape Recorder

CCRS considers this equipment to be essential to undertake these missions. The real-time display interface would be specially built by

Canadian industry based on an existing and proven CCRS design.

The thermal infra-red region of the electro-magnetic spectrum (a wavelength of 8-14 micrometers) is very useful in the detection of oil. Because the equipment is very expensive, very few sensors systems operated in Canada use the thermal infra-red. The pyroelectric vidicon system also gathers and interprets data in the thermal-infra-red region of the spectrum but has a somewhat lower overall performance than the infra-red line scanner. However output from the sensors can be displayed and recorded on conventional television equipment. Complete with a real-time display, the pyroelectric vidicon system is about 1/10 the price of a line scanner. The system is readily available and can be procurred with approximately a three-month delivery schedule.

Although CCRS currently has a laser fluorosensor, the capabilities of the sensor are limited to the gross identification of oil. The addition of fluorescence lifetime channels would make the identification less subject to anbiguous results and would also allow for a form of oil classification to be undertaken. This would be of benefit to Canada's overall oil spill response capabilities as it would be used not only in the Beaufort Sea but for any oil spill of any type in Canadian waters. Modification to the existing sensor to add the fluorescence lifetime channels would be undertaken by Barringer Research Ltd. of Toronto.

A small, relatively inexpensive (220) radio tracking buoy that will move with a surface and sub-surface oil slick has been developed by a small Canadian company, Orion Electronics Ltd. of Saulnierville, Nova Scotia. The device has been tested and found to be effective by the Environmental Protection Service and the Canadian Coast Guard in tracking the movement of

oil under poor weather conditions.

Because visual plotting of the movement of oil slicks may be hampered by fog, high winds and snow, the purchase of one hundred and fifty radio-tracking buoys and receiving antenna is recommended.

During the Period of ice cover, oil from a blowout in the transition zone could be incorporated into the ice sheet and be moved considerable distances under the influence of currents and winds in the Beaufort Sea. In order to determine the area affected, the need for studies to determine the effects of the oil on marine mammals, birds and the impacts on the under-ice flora and fauna, it will be necessary to accurately plot the path of the oil in and under the ice.

A macro/micro tracking system as described in Appendix 2 has been recommended as a result of research undertaken under the auspices of AMOP. At the present time only one Random Access Measurement System (RAMS) buoy is available and has been loaned to Canmar for use at the suspected site of a 230-ton spill of diesel fuel from the icebreaker "John A. MacDonald" in Franklin Bay. It is estimated that the track of an oil slick under ice cover in the Beaufort Sea could move at least 1000 km. In order to adequately plot the movement of the slick a system consisting of at least 10 RAMS buoys and 25 micro-locator buoys is required. At the present time this equipment is not present in the government inventory and should be purchased.

In order to integrate data from toxicity studies and distribution of oil in the water column to predict concentration and distribution of hydrocarbons and the resultant biological impacts that may be anticipated it will be necessary to monitor sub-surface currents. Automatic recording current meters are expensive to purchase and are in use on a regular basis and thus unavailable

for an emergency program such as the scientific response plan. At present there are some 25 NEYRPIC current meters in storage at the Institute of Ocean Sciences. These are not compatible with the present-day analytical procedures but could be brought up to standards with modifications worth $900 per meter. The use of this equipment would not be restricted to the Beaufort Sea but would be available for use in any oil spill situation for which current information was required.

Other equipment requirements are detailed in Appendix 2.

Towards a National Scientific Response Plan

The Beaufort Sea Scientific Response Plan should not be considered as a separate entity but rather as the first of a series of area specific plans that will eventually provide a scientific response to oil spills anywhere in Canada's extensive coastal zone. Equipment requested in this submission can be used to study the fate, behaviour and effects of oil in any marine area and is not restricted solely to the Beaufort Sea area. The basic study package can be readily adapted to meet area specific requirements using area specific scientific expertise and logistical arrangements.

The Western and Northern Regional Board of the Department of Fisheries and the Environment has recognized the potential for an oil spill in the Lancaster Sound, Baffin Bay and Davis Strait and has initiated the development of a Scientific Response Plan for these areas. In addition, considerable interest in the need for a formal Scientific Response Plan has been shown by Fisheries and Oceans establishments on Canada's east coast. It is anticipated that a concerted effort will be made to weld these area specific plans into a plan with national scope using a pool of specialized talent and equipment.

In view of the increasing level of exploration activity and the increase in tanker traffic in Canada's coastal zone and the inevitability of a major oil spill, the development of a national Scientific Response Plan should be given high priority.

APPENDIX 2

SCIENTIFIC STUDIES TO BE UNDERTAKEN IN RESPONSE TO AN OIL SPILL IN THE BEAUFORT SEA

TABLE OF CONTENTS

SCIENTIFIC STUDIES TO BE UNDERTAKEN IN RESPONSE TO AN OIL SPILL IN THE BEAUFORT SEA

INTRODUCTION		1
1	Monitoring the Movement of Oil	5
	1A Remote Sensing	6
	1B Radio Tracking of Surface Oil	14
	1C Radio Tracking of Oil Under Ice	16
2	Factors Affecting the Movement of Oil	22
	2A Effects of Surface Currents and Winds	22
	2B Effects of Sub-Surface Currents During Open Water	26
	2C Effects of Under-Ice Currents	29
	2D Effects of Under-Ice Topography	32
3	Monitoring of Blowout Plume	36
4	Deposition and Decomposition of Spilled Oil	41
	4A Oil in the Water Column	41
	4B Oil in the Coastal Zone	46
	4C Oil in Sediment-Laden Waters	53
	4D Chemical Weathering of Oil	57
	4E Microbial Decomposition of Oil	61
5	Toxicity of Spilled Oil	64
6	Effects of Oil and Coastal Ecosystems	70
7	Effects of Oil on Under-Ice Flora and Fauna	78
8	Effects of Oil on Plankton and Fish Populations	83
9	Effects of Oil on Waterfowl	87

9A Bird Mortality During Spring Migration 88

9B Bird Mortality of Moulting Sea Ducks 91

9C Mortality of Birds in Offshore Open Waters 95

9D Effects of Storm Surges on Birds 97

10 Effects of Oil on Seals 99

10A Spring Distribution and Numbers of Seals 100

10B Effects on Seals in the Fast Ice Zone 102

10C Effects on Seals in the Transition Zone 105

11 Effects of Oil on Polar Bears 107

12 Effects of Oil on Whales 110

12A Effects on Whales During Spring 110

12B Effects on Whales During Summer 112

13 Effects of Oil on Human Utilization of Wildlife 115

LITERATURE CITED 117

SCIENTIFIC STUDIES TO BE UNDERTAKEN IN RESPONSE TO AN OIL SPILL IN THE BEAUFORT SEA

Introduction

Although the general aspects of an oil spill can be described in advance, an oil spill is an unpredictable event and the specific characteristics of a spill will be known only when the spill occurs. Consequently, a response plan must be flexible in order that any oil spill situation can be readily addressed. Study descriptions have accordingly been presented in small, relatively discrete units that can be conducted individually, combined with other studies, or not conducted at all, depending on the circumstances associated with the particular spill.

In the various study descriptions, the importance of each study by itself, the importance as a prerequisite for other studies, and the importance in the interpretation of other studies have each been indicated. Specifically the study descriptions include the following:

1) brief discussion of the rationale for the study,
2) objectives,
3) methods,
4) timing of study,
5) criteria for initiation,
6) government agency and contact persons,
7) personnel requirements,
8) equipment requirements both in readiness on site and on hand elsewhere,
9) logistic support,
10) funds required both to prepare and to implement the study,

11) priority of the study, and

12) relationship to other studies.

The timing of studies refers to the period of year (e.g. spring breakup, open-water period) during which the study should be conducted.

The criteria for initiation generally indicate the oil spill circumstances under which the study should be conducted. Occasionally the criteria will include other studies in the plan that are prerequisites for the study, or a study or development of methodology that should be conducted before any spill occurs.

The government agency listed for each study is generally the one that would logically be assigned the responsibility for the study because of the particular expertise of the staff. The contact person is usually the head of the division (section, department, etc.), but where a scientist has indicated a desire to do the particular study, his name has also been included.

The personnel requirements for a study generally identify the types of personnel required to conduct the study. Memoranda of agreement have been signed by Directors or Directors-General of the Department of Fisheries and Environment and by the Deputy Minister of the Department of Energy, Mines and Resourrces that, in the event of an oil spill in the Beaufort Sea, the personnel identified in the response plan will be released from ongoing commitments in order to participate in the implementation of the Scientific Response Plan.

Equipment requirements in readiness are those that should be kept on hand in order to be available immediately upon need.

Logistic support is difficult to realistically estimate (particularly aircraft time) because it depends on the sampling intensity, which will be determined by the characteristics of the spill.

Studies have been assigned priorities in order to stress those studies in this report that it is most important to conduct in order to attain the objectives of the scientific response plan.

The priorities have been listed as first, second, third or fourth level. First level studies are those studies that are prerequisites for the successful implementation of all other portions of the Scientific Response Plan. Second level studies are those which will adequately and convincingly measure immediate impacts of the oil spill, that will provide adequate information to improve predictive capabilities with regard to oil spills or that are critical to long-term studies on the recovery rate of impacted areas. Third level studies are those studies that would assist in improving predictive capabilities or measuring impacts, but that would probably be severely limited in the amount of data that could be collected because of logistical difficulties. Fourth level studies are studies that are useful but less critical than the higher priority studies in meeting the objectives of the plan.

The study descriptions that follow, fall under the following main headings:

1) Monitoring the Movement of Oil
2) Factors Affecting the Movement of Oil
3) Monitoring of the Blowout Plume
4) Deposition and Decomposition of Spilled Oil
5) Toxicity of Spilled Oil

6) Effect of Oil on Coastal Ecosystems

7) Effects of Oil on Under-Ice Flora and Fauna

8) Effects of Oil on Plankton and Fish Populations

9) Effects of Oil on Water Birds

10) Effects of Oil on Seals

11) Effects of Oil on Polar Bears

12) Effects of Oil on Whales, and

13) Effects of Oil on Human Utilization of Wildlife

1. Monitoring the Movement of Oil

In the past when large quantities of oil have been accidentally spilled in the marine environment (e.g. Torrey Canyon spill, 1967; Arrow, spill 1970; Argo Merchant spill, 1976; Amoco Cadiz, 1978) the oil has generally moved large distances and has spread to cover extensive areas. This is expected to be the case in the event of a major spill in the Beaufort Sea, particularly in the case of a spill from a well blowout in the transition zone (Milne & Smiley, 1976).

During oil spills, oil also dissolves and disperses into the water column where water currents can carry it substantial distances, usually accompanied by further dilution from mixing in the water column. During a blowout there is considerable turbulence where the oil is released and the quantities of oil entering the water column could be substantial. In contrast to the movement and fate of surface oil (which can be followed fairly readily through visual means) the movement and fate of sub-surface oil cannot be monitored quantitatively in a detailed manner at the present time, largely because the means of rapidly detecting oil in the water column are undeveloped.

The studies in this section are restricted to the movement of surface oil for the following reasons:

1) it is the only type of oil whose movements can be monitored directly and in detail,
2) a major portion of the spilled oil occurs as surface oil during the early stages following a spill, and
3) surface oil frequently has very major impacts.

1A. Remote Sensing

Remote sensing of the oil spill will be essential to any scientific response to an oil spill in the Beaufort Sea and should be the first priority in such a response. Remote sensing will also be essential for efficient countermeasure activities.

From remote sensing flights, qualitative and quantitative information can be obtained on the location, movement, extent, and fate of oil slicks; on the location and extent of shorelines affected by oil; and, in the event of a blowout, on the behaviour of oil in the vicinity of the blowout plume. On a short-term basis, this information (in conjunction with that on the availability of logistic support) will enable a scientific coordinator to identify those scientific studies that are warranted by the circumstances. On a long-term basis, this information will be essential to the interpretation of the fate and the environmental impact of the spill, and will serve to increase the predictive capabilities with respect to the behaviour, fate, and environmental impact of future oil spills in Arctic waters.

Objectives

1) To record quantitatively and qualitatively the location, movement, extent, and fate of oil slicks from the spill.

2) To provide baseline information necessary to determine the need for other studies contained in the scientific response plan, and the location, timing and intensity of implementation of these studies.

Methods

In the event of a major oil spill, the following aspects of the spill will be investigated through a remote sensing program:

1) To obtain position data on the distribution of the spilled oil on a daily basis (if possible).

2) To determine the direction and rate of movement of slicks.

3) To determine the movement of oil in ice-infested waters.

4) To determine the behaviour of oil in lead systems.

5) To examine the movement of oil up through the ice during the spring melt period and the extent of the area over which this occurs.

There are two forms of remote sensing that will be conducted during an oil spill. The first form will be with a Canada Centre for Remote Sensing aircraft equipped with a variety of sensors such as:-

Laser Fluorosensor

Multispectral Scanner

Multi-Element Electro-Optical Imaging System

Low Light Level Television

Profiling Spectrometer

Multi-Band Photometer

Metric Mapping or Reconnaissance Camera

Synthetic Aperture Radar

Microwave Scatterometer

Microwave Radiometer

Pyroelectric Vidicon

Colour Television

supported by appropriate Data Acquisition Systems, Real Time Tactical Displays

and sophisticated Navigation Systems. Such a mix of sensors will allow the best chance of detecting, identifying, tracking and recording the behaviour of any spilled oil lying on the surface of the water, on the surface of the ice or in the leads, under fair or poor weather conditions, during daylight or at night.

Information gained from these flights will be of prime importance to aid the on-scene commander of the countermeasures group, to determine the need for other scientific response studies and to provide a record of the behaviour of events during the spill.

The second form of remote sensing that will be conducted will be of a reconnaissance nature under good weather daylight conditions using a downward looking medium format camera, and an appropriate navigation system to fix the position of the photographs taken. An aircraft of the light twin engined class would be used.

Whenever possible, the Canada Centre for Remote Sensing aircraft with its highly advanced sensors and systems will be used. However, as these aircraft serve the remote sensing needs of a very large number of users, such an aircraft cannot always be made available exclusively to support the response to an oil spill in the Beaufort Sea although every effort will be made, especially during key periods of the response. (Indeed, a formal memorandum of agreement has been signed by the Deputy Minister of the Department of Energy, Mines and Resources stating that the Canada Centre for Remote Sensing will do everything possible to ensure that one of its aircraft, complete with sensors, scientists and crew, will be made available to carry out remote sensing missions over an oil spill if the need arises.) At other times, the second form of remote sensing will be employed (using the photo-

graphic reconnaissance aircraft) to provide continuity of data on a daily or more frequent basis as necessary.

Timing of Study - Because of ice cover obscuring the oil from around November till April, the majority of the remote sensing flights will, in general, be carried out between April and November during the duration of the spill.

Criteria for Initiation

A remote sensing study should be initiated for any spill for which a scientific response if considered.

Government Agency and Contact Person

Agency - Canada Centre for Remote Sensing
Department of Energy Mines & Resources
2464 Sheffield Road
Ottawa, Ontario K1A 0Y7

Contact - Dr. R.A. O'Neil
Telephone - (613)998-9060

Photographic Remote Sensing

Agency - Ocean & Aquatic Sciences
Fisheries & Marine Service
Institute of Ocean Sciences
P.O. Box 6000, 9860 W. Saanich Road
Sidney, B.C. V8Z 4B4

Contact - Allen R. Milne
Head, Arctic Marine Science
Telephone - (604)656-8249 Office
(604)656-1650 Home

Personnel Requirements

Scientists familiar with remote sensing of oil spills are required for directing and participating in the missions, analyzing the results, preparing reports and working closely with the scientific coordinator(s) and the on-scene commander of the countermeasures team.

During winter flights, a person experienced in winter survival should accompany the missions.

Equipment Requirements

In readiness:

- pyroelectric vidicon system
- lifetime channels for laser fluorosensor
- real time display for scanners
- medium format camera with annotation and levelling system
- support items (arctic clothing, hand-held cameras, binoculars, etc.)

Logistic Support

The calculation of aircraft time is very artificial because of the unpredictability of the weather variable and the magnitude of the spill response required. In the event of a spill which is of sufficient magnitude to require the implementation of the scientific response plan but not of a sufficient magnitude to warrant the implementation of the government countermeasures plan, remote sensing of the spill is the responsibility of the scientific response plan. However, when it is necessary to implement the government countermeasures plan, remote sensing of the spill becomes the responsibility of the countermeasures plan.

Logistic Support Requirements:

- 480 hours twin-engine fixed wing aircraft (Cessna 337)
- 100 hours of CCRS aircraft time
- 30 hours of helicopter time (Bell 206)
- accommodation in Tuktoyaktuk for up to 12 months for two persons (pilot and observer)
- accommodation in Tuktoyaktuk or Inuvik for up to 35 days for 11 persons (CCRS aircrew)
- transportation Victoria-Tuktoyaktuk to facilitate personnel relief every three weeks
- air freight

For the above calculations of aircraft time, it has been assumed that there has been no need to initiate the government countermeasures plan and that all remote sensing is undertaken by the scientific response plan. In actual fact flight time requirements may be considerably less due to the assumption of remote sensing responsibilities by the countermeasures team. Remote sensing would be required between late April and early November. CCRS aircraft would be required for five of the 28 weeks. Of the remaining 23 weeks, flying by fixed-wing aircraft is assumed to be possible for only 75% of the time or approximately 120 days. A flight has been assigned an average time of four hours.

In winter a Bell 206 helicopter could be used over the ice. Only occasional flights will probably be required, and these flights could be combined with flights required to deploy radio beacons for tracking ice (see study 1C Radio Tracking of Oil Under Ice).

Funds Required

To prepare:	pyroelectric vidicon system	$30,000
	lifetime channels for fluorosensor	50,000
	real time display for scanners	84,000
	medium format camera system	2,500
	support items	7,500
	Total to prepare	$174,000
To implement:	CCRS aircraft operating costs	120,000
	light twin engine aircraft operating costs	108,000
	helicopter operating costs	10,500
	accommodation	72,000
	air fares	10,400
	native assistance	7,500
	film, tape, etc.	22,000
	air freight	2,600
	Total to implement	$353,000 *

Priority - First Level

Relationship to Other Studies - This study will be required to determine the need for the following studies and the timing and location for their implementation:

2D Effects of Under-Ice Topography

4B Oil in the Coastal Zone

4C Oil in Sediment-Laden Waters

6 Effects of Oil on Coastal Ecosystems

8 Effects of Oil on Plankton and Fish Populations

* Implementation costs of this study would be recoverable from the polluter.

9A Bird Mortality During Spring Migration

9B Mortality of Moulting Sea Ducks

9C Mortality of Birds in Offshore Open Waters

9D Effects of Storm Surges on Birds

10A Spring Distribution and Numbers of Seals

10B Effects on Seals in the Fast Ice Zone

10C Effects on Seals in the Transition Zone

11 Effects of Oil on Polar Bears

12A Effects on Whales During Spring

12B Effects of Whales During Summer

The following studies require that the Remote Sensing study be carried out in conjunction with them in order to ensure meaningful results:

1B Radio Tracking of Surface Oil

2A Effects of Surface Currents and Wind

2D Effects of Under-Ice Topography

2B Effects of Sub-surface Currents During Open Water

4B Oil in the Coastal Zone

4D Chemical Weathering of Oil

4E Microbial Decomposition of Oil

The results of the Remote Sensing study will assist in the interpretation of the results of most other studies and particularly the following studies:

1C Radio Tracking of Oil Under Ice

3 Measurement of Plume Profile

4A Oil in the Water Column

Studies 1B, 1C and 2A are dependent on the aircraft support described in the Remote Sensing study.

1B Radio Tracking of Surface Oil

During open-water periods in the Beaufort Sea, weather conditions such as fog, high winds, or snow will sometimes prevent tracking of oil slicks by remote sensing. In the past it has often been very difficult with remote sensing to relocate oil slicks following an interruption in surveillance. Such slicks have often been assumed to have either dispersed or been carried out to sea only to have the oil reappear on a shoreline. Apparently the lost oil had formed an oil-in-water emulsion located just below the water surface; and, although it still travelled with the surface currents, it was not so readily detectable from the air. A radio tracking buoy that will stay with oil slicks (i.e., it moves in the same manner as the oil) has been developed and tested; it should greatly assist the remote sensing of oil spills in the Beaufort Sea. Information on the rate and direction of movements of radio buoys will be necessary to interpret the effects of surface currents and wind on the movement of oil slicks on open water.

Drift cards have also been used as a means of determining possible movements of oil slicks in open water, but the value of the cards depends entirely on their being found when they wash ashore. In the sparsely populated Arctic this might prove to be a major limitation. Clean-up crews working on oiled beaches and scientists working on other studies within the response plan would probably be the source of most of the returned cards.

Objectives

1) To provide a means of relocating large oil slicks after interruptions in the remote sensing flights due to weather.

2) To provide a basis for accurately measuring the rate and direction of movement of oil slicks.

Methods - Large slicks that escaped confinement would be marked with two or more radio buoys (at least one as a back-up) during remote sensing flights in order that the slicks could readily be relocated when flights resume following interruption by bad weather. In general, the pattern of release of radio buoys would be determined by the nature of the spill.

Although drift cards are not a radio-tracking method, they are cheap to produce. The release of individually marked cards in both large and small slicks could provide some useful qualitative information on the movements and fates of oil. The use of fluorescent orange cards might increase their conspicuousness (depending on the degree to which they become oil-covered) and hence the number of returns. Even oil-covered drift cards could be found in the course of cleaning oiled beaches.

Both the radio buoys and the drift cards would be released from the remote sensing aircraft. Tracking of the radio buoys would also be done by the remote sensing aircraft.

The analysis of data and preparation of the report on the rates and directions of movements of oil slicks would be combined with that on the effects of surface currents and wind on the movement of oil (study 2A).

Timing of Study - Duration of the open-water period.

Criteria for Initiation - Any oil spill that occurred during the open-water period and for which the "Remote Sensing" study was initiated.

Government Agency and Contact Person - Same as Remote Sensing study.

Personnel Requirements - This study would be carried out as part of the Remote Sensing study. Although it is not essential, it would be preferable if the observer has had some previous experience in deploying and tracking these buoys.

Equipment Requirements

100 radio buoys

tracking antenna

1000 drift cards

Logistic Support - Utilizes logistic support of study 1A Remote Sensing.

Funds Required - To prepare:

radio buoys* (100 @ $220)	22,000
tracking antenna	1,100
drift cards	900
TOTAL	24,000

To implement: Utilizes same aircraft funds described in 1A Remote Sensing.

*Significant cost reductions are available through volume discount and capacity of manufacturer to recycle used buoys.

Priority - First Level

Bad flying weather could be more the rule than the exception in the Beaufort Sea; this would make radio buoys very important for remote sensing.

Relationship to Other Studies - This study would be combined with the Remote Sensing Study (1A). Results of this study are necessary for the interpretation of the results of studies 2A Effects of Surface Currents and Wind, 4D Chemical Weathering of Oil, and 4E Microbial Decomposition of Oil; the results would also assist in the interpretation of the study 4C Oil in Sediment-Laden Waters.

1C Radio Tracking of Oil Under Ice

During the winter it is expected that oil released from a blowout on the sea floor will gather under the ice and that much of this oil will become

incorporated into the ice. Although there will be some movement of the under-ice oil relative to the ice (see studies 2C and 2D), major movements of the oil are expected to take place only in association with movements of the ice. In the fast ice zone, where the ice moves very little, the oil is expected to remain in the vicinity of the blowout. In the transition zone, where the ice normally moves substantial distances during the winter, it should be possible to determine the location of oil released during the winter by placing radio beacons on the ice that moves over the blowout and then tracking the movement of this ice.

Information from this study will be important for the determination of the area under the ice that is affected by the blowout. This will determine the need for biological studies on the effects of oil on populations of birds, polar bears, seals and whales that may encounter the oil on the ice, under the ice, or in leads. The information will also be useful in interpreting the significance of the results of the study on the effects of oil on under-ice flora and fauna.

Objectives - To track the movement of ice that moves over an oil well blowout in order to determine the extent of the area over which the oil spreads during the period of ice cover.

Methods - Two tracking systems would be used:

(1) A macro, long-range tracking system and;

(2) A micro, spot location system

The macro components will have a positioning capability anywhere on the earth's surface to an accuracy of 2km and an unlimited range. Since the width of the slick is anticipated to be only 100 m, the micro units must have an accuracy of a few tens of metres.

Due to the limitations of aircraft navigation systems, it is not possible to use a single system for both macro and micro determinations. Most aircraft long-range systems have an accuracy of a kilometre or more and, hence, could not find a 100 m path without using a visual search routine. The macro system would allow flight to the general area of the slick and the micro system would provide homing to the actual slick location. The micro system should have a range of 40 km, a homing accuracy of 10 m and should be capable of operating under Arctic conditions for a period of at least nine months.

The macro system would consist of RAMS (Random Access Measurement System) buoys. These would be deployed, as required, on large multi-year ice floes that move over the blowout site. After the buoy had been moved approximately 100 km another unit would be deployed. A one-second UHF radio signal would be produced each minute. The signals would be monitored daily by satellite. At the present time, the French ARGOS satellite and data collection system could be utilized. This system has a user fee in the order of $20/day/transmitter.

The micro homing system consists of two subsystems: a small pulsed HF or VHF transmitter and a direction finder in the search aircraft and; a passive radar reflector which would be visible on the surveillance radar of the CCRS aircraft. These systems have been widely used in the Arctic for site relocation and the recovery of scientific equipment.

A RAMS buoy would be deployed on the ice passing over the blowout site and another unit deployed at the well site after the ice had moved the first buoy 100 km. At more frequent intervals, a micro system would be deployed at the well site. This combination will allow a wide variety of aircraft to be used for tracking and will have an inherent redundancy.

A micro system is being developed under the auspices of the Environmental Protection Service's Arctic Marine Oilspill Program (AMOP).

Timing of Study - Duration of the period in which ice covers the blowout site.

Criteria for Initiation - This type of study should be initiated whenever there is a major spillage of oil under ice in the transition zone. In the fast ice zone the use of RAMS buoys should be considered optional; but their use would guard against any unexpected ice movements.

Personnel Requirements - One person who is familiar with the deployment of RAMS buoys would be required for one or more days according to the extent of ice movement during the winter. Because flights to deploy buoys would also be used for remote sensing, the remote sensing observer would presumably fill this role. A native assistant experienced in winter travel and survival on the ice should accompany the pilot and observer; he would be required to assist with the deployment of the buoys.

Government Agency and Contact Person

Agency - Arctic Marine Sciences
Institute of Ocean Sciences
Department of Fisheries and Environment
P.O. Box 6000, 9860 W. Saanich Road
Sidney, British Columbia V8Z 4B2

Contact - Mr. A.R. Milne, Head
Telephone: (604) 656-8249

Equipment Requirements

- ice auger
- 10 RAMS buoys
- 25 micro-system transmitters

Logistic Support - Utilizes same ligistic support as that described for Remote Sensing (1A) during the winter.

Funds Required

To prepare:	RAMS buoys (10 @ $4,500)	$45,000
	Micro system (25 @ $700)	17,500
	Automatic Direction Finder Receiver	2,500
	Sub-total to Prepare	$65,000
To implement:	Satellite fees	$20,000
	Native Assistant	1,000
	Sub-total to Implement	$21,000 *
	TOTAL	$86,000

Priority - First Level

Relationship to Other Studies - This study is ligistically dependent on the helicopter support described in the Remote Sensing Study (1A). This study is required to determine the need for the following studies:

7 Effects of Oil on Under-Ice Flora and Fauna

8 Effects of Oil on Plankton and Fish Populations

9A Bird Mortality During Spring Migration

10A Spring Distribution and Numbers of Seals

10C Effects on Seals in the Transition Zone

11 Effects of Oil and Polar Bears

12A Effects on Whales During Summer

* Implementation to be undertaken by Government Contingency Plan. Costs are recoverable from the polluter.

This study will be necessary for the interpretation of the results of studies 2D Effects of Under-Ice Topography and 4D Chemical Weathering of Oil. It will assist in the interpretation of the results of study 4A Oil in the Water Column.

2. Factors Affecting the Movement of Oil

In order to improve the general predictive capabilities with regards to the impacts of oil spills not only in Arctic waters but in any of Canada's coastal waters it will be necessary to know not only where oil goes and what its impacts are, but also the factors that have caused the oil to move. Major factors causing oil to move in the Beaufort Sea will be currents, winds and ice. These factors will be interrelated in their effects on the movement of oil.

2A. Effects of Surface Currents and Winds

Surface currents and winds are the primary factors responsible for the movement of oil slicks and for the deposition of oil in coastal areas (where the greatest impact usually occurs). In the Beaufort Sea, oil spills are expected to occur on the continental shelf. Surface currents over the continental shelf area during the open-water period vary considerably. They are driven primarily by the Mackenzie River flow and by the wind (MacNeill and Garrett 1975). Northwest and southeast winds are the predominant winds during the open-water periods. Surface currents tend to flow in a northeasterly direction along the coast during northwest winds, but they move offshore in a northwest direction during southeast winds.

Oil slicks tend to move with the surface currents but there is also a force component exerted directly on the oil by the wind (Mattson and Chan 1976) that could cause the oil to move in directions somewhat different from those of the surface currents. This aspects will be of most interest during northwest winds; the winds will tend to force oil towards the coast but the

currents will tend to sweep the oil northeastwards towards the Amundsen Gulf. Knowledge of the fate of oil under these conditions (see also studies 4B, 4C) will improve predictive capabilities with regard to the fates of oil spills in general.

Measurement of the direction and velocity of surface currents at and near oil slicks will be useful only if similar data are obtained on winds and on the movements of oil slicks (see 1B Radio Tracking of Surface Oil).

Objective

To describe quantitatively the effects of surface currents and wind on the movement and fate of oil slicks.

Methods - Current drogues will be used to obtain data on the velocity and direction of surface currents. Drogues will be released at the same time and place as oil-tracking buoys. By recording the position of drogues and buoys at 24 or 12 hr intervals, information can be obtained on the velocity and direction of movement of both surface currents and oil slicks.

Deployment and tracking of drogues and buoys will be carried out during remote surveillance over flights. However, it would occasionally be desirable to make tracking flights more often than once per day and supplementary aircraft time has accordingly been included in the logistic requirements of this study.

The current drogues will be equipped with transmitting devices of the same design as the radio tracking buoys described in Study 1B.

In the event of an oil spill, sufficient information on winds in the area will presumably be available. Weather data are routinely monitored from the drilling vessels and at DEW sites on the Beaufort Sea coast. Weather data (particularly wind) should be recorded on a regular basis from any ships operating in the area of the spill or during any studies conducted on shore

or on the ice.

A marine type U2A anemometer and temperature sensing equipment will be required to ensure that a ship in the area of the spill can gather suitable wind and temperature data.

On the basis of wind and current information it should be possible to quantify the relative importance of these two factors in the observed movement of oil slicks.

Timing of Study - Duration of the open-water period.

Criteria for Initiation - The implementation of this study would depend on the occurrence of any oil spill during the open-water season and on the implementation of studies 1A, Remote Sensing, and 1B, Radio Tracking of Surface Oil.

Government Agency and Study Leader

Allan R. Milne, Head

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for weather - David Fraser, Head
Arctic Weather Central
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Personnel Requirements - The field portion of this study will require a person who was experienced in deploying and tracking current drogues and oil-tracking buoys and an oceanographer to analyze data on winds and on the movement of drogues and tracking buoys.

A meteorological technician will be required to install the meteorological equipment.

Equipment Requirements

- 50 radio buoys suitably modified to function as current drogues
- tracking antenna (same unit as that described in Study 1A)
- 1 marine type U2A anemometer
- 1 temperature sensing apparatus

Logigistic Support

- 30 hours twin-engine fixed-wing aircraft (Cessna 337) with suitable positioning system plus aircraft time of Aerial Reconnaissance Study (2A)
- accommodation in Tuktoyaktuk for one person (2 1/2 months maximum)
- accommodation in Tuktoyaktuk for a second person for 10 days
- air fare Victoria-Tuktoyaktuk-return (2 trips)
- air fare Edmonton-Tuktoyaktuk-return (2 trips)

Funds Required

To prepare:

radio tracked current drogues

50 @ $420		$21,000
Marine type U2A anemometer		2,500
Ventilated Steven screen with thermometers		500
	sub-total	$24,000
To implement:		
aircraft charter		$ 6,760
accommodation		5,625
air fare		2,015
air freight		600
	sub-total	$15,000
	TOTAL	$39,000

Priority - Second Level

Relationship to Other Studies - This study would be carried out as part of the Remote Sensing study (1A) and in conjunction with study 2A Radio Tracking of Surface Oil. The results of this study and those of the studies 4B Oil in the Coastal Zone and 4C Oil in Sediment-Laden Waters would provide a relatively complete description of the short-term fate of surface oil in coastal areas.

2B. Effects of Sub-surface Currents During Open Water

Sub-surface currents for the continental shelf area of the Beaufort Sea are variable; they often flow in directions that are different from those of the surface currents. The main purpose of monitoring sub-surface currents during the open-water period is to determine where and how fast the dissolved or dispersed oil from a blowout will be moved. When this information is combined with that from detailed studies on the quantity and quality of

hydrocarbons present in the water column (see study 4A) and from toxicity tests on the oil (see study 5), it provides information that can be used to predict both the concentrations and distributions of dissolved or dispersed hydrocarbons and the resultant biological impacts that could be expected to occur in other areas under similar conditions. A study description for monitoring sub-surface currents during the open-water period is presented below.

Objectives

To monitor the rate and direction of flow of sub-surface currents in the vicinity of a blowout during the open-water period.

Methods - Strings of current meters capable of monitoring rate and direction of flow, temperature, and salinity of water at various depths for extended periods of time will be deployed in a circular or triangular grid around the blowout at a distance sufficient to avoid monitoring localized currents generated by the plume. Other strings of current meters would be placed at still greater distances from the blowout site. A string of current meters would contain at least three meters and would consist of a heavy anchor, several current meters separated by suitable lengths of cable, a large float to hold the string upright, and an acoustical release mechanism immediately above the anchor. A suitable vessel will be required to deploy and retrieve the current meters.

Timing of Study - The study would be carried out during the open-water period for as long as ships could operate in the vicinity of the blowout without danger of being trapped by the ice.

Criteria for Initiation - This study would be implemented only in the event of a long-term spill such as an oil well blowout, and probably only

for a spill occurring during the first half of the open-water period.

Personnel Requirements - The study will require a physical oceanographer and an assistant to conduct the field portion of the study, and to interpret and summarize the data.

Government Agency/Project Leader

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Equipment Requirements

- 25 current meters
- equipment for salinity/temperature/turbidity measurements

Logistic Support

- deep-water vessel
- accommodation at Tuktoyaktuk for two persons for two months
- air fare: Victoria-Tuktoyaktuk return (4 trips)

Automatic current meters are expensive units to purchase ($5,500 each). This situation can be remedied by modifying existing units which, at present, are not compatible with present-day analytical procedures. There are 25 NEYRPIC current meters in stock at the Institute of Ocean Sciences which could be brought up to present-day standards with modifications worth $900 per meter.

Funds Required - To prepare: modification of 25 NEYRPIC current meters @ $900/meter $22,500

sub-total $22,500

To implement:	accommodation	$ 7,800
	air fare	2,400
	air freight	5,300
	sub-total	$15,500
	TOTAL	$38,000

Priority - Third Level

Relationship to Other Studies - This study would be conducted only in conjunction with the hydrocarbon analysis program described in study 4A: Oil in the Water Column. The results of these studies and study 1A: Remote Sensing, would be required for the interpretation of the study 8: Effects of Oil on Plankton and Fish Populations.

2C. Effects of Under-Ice Currents

The winter movement and distribution of oil from a blowout in the fast ice zone will be determined by the direction and the speed of currents immediately below the under-surface of the ice, by the topography of the under-ice surface (see study 2D) and, to a lesser extent, by sub-surface currents.

In the transition zone the movement and distribution of oil that is released from a blowout will be determined by the ice movements, by the currents immediately under and sub-surface to the ice, and by the ice morphology (i.e., shallow-draught first-year ice vs. deep-draught multi-year ice). Ice movement will be the most important of these three factors; it will probably completely mask the effects caused by currents and by ice morphology. A study of ice movement has previously been described (see 1C).

The monitoring of under-ice currents alone is of limited interest; but when it is combined with the study on the effects of under-ice topography on the movement of oil the information obtained will be useful in predicting the impacts of oil spills under ice-covered waters (see studies 2D, 7, and 9A).

Methods - Any attempts to deploy current meters for extended periods in the transition zone will probably result in their loss. In the fast ice zone current meters could be deployed through the ice and retrieved the following summer. This method, however, would require that the top of the current meter float be well below any ice that might form during the winter and that the deployment position be precisely known in order that a vessel could locate them during the open-water period. This method would not give information on the currents immediately below the ice surface - the currents of greatest importance to the movement of oil.

As an alternative, it is proposed that several helicopter trips be made to the vicinity of the blowout site in order to take current profiles and salinity-temperature-turbidity measurements through the ice at several locations surrounding the blowout site (cf. Herlinveaux and de Lange Boom 1975). The location of these sites will depend on safety considerations (e.g., presence of flammable gas under the ice or seeping through it; countermeasures activity). The timing of these flights will depend on weather conditions, ice conditions, and available daylight. Because there is little available daylight between late November and late January, flights may not be feasible until February.

Timing of Study - November (perhaps) and during the winter ice period between late February and May.

Criteria for Initiation - An oil well blowout that continued to flow

during the winter. Unless study 2D is also conducted, there is little value in conducting this study.

Government Agency and Project Leader

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Personnel Requirements - One person, experienced in conducting current profiles and salinity-temperature-turbidity measurements, and an assistant would be required to conduct the field work. The analysis and summarization of data would require a physical oceanographer. The party should also include a native assistant familiar with survival and travel on ice; this person would probably be able to function in the capacity as the assistant to the oceanographer.

Equipment Requirements

- current meters
- ice auger
- winch
- equipment for salinity-temperature-turbidity measurements

Logistic Support

- 20 hrs helicopter (Bell 205) [estimated]
- accommodation at Tuktoyaktuk for two months (2 people)
- air fare: Victoria-Tuktoyaktuk (4 trips)

Funds Required - To prepare: nil

To implement:	helicopter	$16,000
	air fare	$ 2,400
	accommodation	7,800
	air freight	1,000
	miscellaneous	500
	native assistant	3,300
	sub-total to implement	$31,000
	TOTAL	$31,000

Priority - Third Level

Relationship to Other Studies - This study would be carried out only in conjunction with the winter portion of the study on Oil in the Water Column (4A) and with the studies on Ice Movement (1C) and the Effects of Under-Ice Topography (2D). The results of these three studies and the study on Toxicity of Spilled Oil (5) will provide some assessment of the impact on under-ice flora and fauna (7) and on plankton and fish populations (8).

2D. Effects of Under-Ice Topography

Oil released under ice (from a blowout) will be moved along under the ice by currents until it collects in pockets on the under-surface of the ice. It is expected that oil stranded in these areas will be frozen into the ice as the ice thickens during the winter.

In the fast ice zone, pressure ridges will probably be the major blockage to the movement of oil under ice. It is in these areas that ringed seals have their breathing holes and birth lairs (see study 10B).

In the transition zone (which is important to wintering seals and to

migrating birds and whales in spring) oil will accumulate in any open leads and in the many under-ice pockets created by the mixture of deep-draught multi-year ice, shallow-draught first-year ice, and recently frozen leads. Because this ice moves to the west (due to the Beaufort Sea gyre), the oil trapped by the ice will be moved to the west (Milne and Smiley 1976). When the ice moves slowly considerable quantities of oil will probably accumulate under and in a relatively small amount of ice; when the ice moves rapidly small amounts of oil will probably be dispersed under and in a large area of ice. Milne and Smiley (1976) predict that the oil will be distributed in a narrow band that could be several hundred kilometers in length.

The actual distribution of oil under or in the ice of the fast-ice zone or the transition zone is of considerable interest in assessing the biological impact of the spill on under-ice flora and fauna, and on birds, seals, polar bears, and whales (see studies 7, 9A, 10A, 10B, 10C, 11, 12A).

During the melt period in May and June, oil trapped in or under the ice will migrate up through the ice and form pools on the surface of the ice or it will be released into leads. A record of the size and distribution of oil pools on the ice surface, relative to ice features such as pressure ridges, would provide quantitative information that could be used to assess the importance of the under-ice topography in the movement of oil under the ice.

Objectives

1) To determine the size and distribution of surface pools of oil and the surface characteristics of ice in the same area.

2) To relate the information on the oil to the under-ice topography.

Methods - Remote Sensing flights would be initiated when oil began to surface (determined by study 1A Remote Sensing) and would probably be continued

for approximately one month (on the basis of information in NORCOR 1975). The frequency of flights would vary depending on weather conditions, but flights could be as often as daily if circumstances warranted them. An accurate positioning of all flight lines would be required. In the fast zone, the area to be sensed would be quite small. In the transition zone, the area could be quite large depending on the movement of the ice. Ideally, the study would be carried out by a CCRS aircraft. The infrared scanners and pyroelectric vidicon would be particularly useful in mapping oil on ice.

It may also be possible to map the oil in and under the ice before it reaches the surface. Present studies on the optical properties of ice- and snow-covered lakes suggest that during spring the surface reflectance of light in the visible and near IR region would provide a means of detecting oil in and under ice (W.A. Adams, pers. comm.). If feasible, this method would reduce the number of flights required for a detailed documentation of the distribution of oil under the ice.

Timing of the Study - Approximately one month commencing when the oil started to surface (some time in early May).

Criteria for Initiation - Any oil spill where large quantities of oil were released under the ice over an extended period of time, either in the transition zone or in the fast-ice zone.

Government Agency and Project Leader

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  Canada Centre for Remote Sensing
  Department of Energy, Mines & Resources
  Ottawa, Ontario

Personnel - CCRS air crew.

Logistic Support

- one CCRS aircraft for one month
- accommodation for one month in Inuvik (flight crew)

Funds Required - To prepare: costs included in study 1A

To implement: costs included in study 1A

Priority - Second Level

Relationship to Other Studies - The Remote Sensing study (1A) will be required to determine the start-up time of this study. The studies 1C Radio Tracking of Oil under Ice and 2C Effects of Under-Ice Currents will be required to interpret the results of this study with regard to movement of oil. The results of this study will be critical to the interpretation of results from studies 7 Effects of Oil on Under-Ice Flora and Fauna, 9A Bird Mortality During Spring Migration, and 10B Effects on Seals in the Fast Ice Zone. It would also be interrelated with the results of two other studies to increase predictive capabilities with regard to movement of oil:

1C Radio Tracking of Oil Under Ice

2C Effects of Under-Ice Currents

3. Monitoring of the Blowout Plume

The only information available on the probable behaviour and plume characteristics of an oil well blowout in the Beaufort Sea has been obtained from related literature and from open-water experiments conducted during the Beaufort Sea project (Topham 1975). No information is available on the effects of an oil well blowout plume on ice cover, or conversely, on the effects of large milti-year floes on a blowout plume. Documentation of what happens at the blowout site would help to increase the predictive capabilities with regard to the movement, fate, and impact of oil that is released from an oil-well blowout in Arctic waters.

The hazards of a blowout situation (large quantities of flammable gas will probably accompany the oil) would preclude the taking of direct measurements in the immediate vicinity of the plume. It may be possible to make some useful measurements of the plume profile with a side scan sonar, but there are some potentially major limitations.

Photographic and written descriptions of both the plume characteristics at the surface of the water and the effects of the plume on the movement and fate of the oil would be very useful. Aspects that should be noted specifically include the following:

1) Does the wave ring have any confining effect on the oil?
2) Does the plume keep water ice-free in the immediate vicinity of the blowout?
3) Does oil flow onto the ice or under it?
4) What happens when various types of ice move over the plume?

Objective

To obtain quantitative measurements on the shape and diameter of the blowout plume in order to put further points on the curves generated from Topham's theory regarding blowout plumes (see Topham 1975).

Method - A side-scan sonar would be used to obtain measurements of the plume profile. The first measurement would be made as soon as possible after the blowout occurred. Further measurements (approximately seven) would be made at monthly intervals (see "Potential Limitations" below) to record any changes in the plume shape and diameter.

Complementary Information Required - In order to put further points on the curves from Topham's theory, it will be necessary to have a good estimate of the rate of release of oil and gas.

Potential Limitations - A side-scan sonar must be within 150 m of the blowout plume in order to obtain an acceptable reading. During the open-water season it is possible that ships will not be able to proceed this close to the blowout site because of safety precautions or clean-up operations (particularly if the blowout has been set afire). Moreover, ships may not be available for the project. During the winter it may not be safe to work on the ice within 150 meters of the blowout site (depending on ice conditions, presence of gas, and countermeasure activities). During certain months of the year, it will be impossible to conduct this study. From approximately late October to late December, ice conditions will prevent ships from reaching the blowout site (depending on the ships, the year, and the location of the blowout), and the lack of a firm ice-cover will prevent the use of helicopters to reach the site. During breakup in May, June, and July similar logistic problems will again occur.

Timing of Study - For the purposes of the response plan, the study would continue for the lesser of one year or the duration of the blowout. It would also be interrelated with the results of two other studies to increase predictive capabilities with regard to movement of oil:

1C Radio Tracking of Oil Under Ice

2C Effects of Under-Ice Currents

Criteria for Initiation - The study would be initiated only if there was a blowout of an oil well on the ocean floor. This type of study would not be relevant to a blowout on an artificial island.

Government Agency and Project Leader

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Personnel Requirements - One person, trained in the use of a side-scan sonar, and an assistant would be required for approximately one day each trip to make the necessary measurements. The actual measurements would require about two hours. Additional time would be required each trip for travel (two days) and for any delays caused by weather or the lack of immediate transportation to the blowout site. During the winter, a native guide should accompany the people making measurements from the ice (four trips).

Equipment Requirements

In Readiness: ice auger - 9"
portable winch with 150 m cable capacity
(already available)

side-scan sonar and associated accessories (available in Victoria)

Logistic Support

- 8 hrs helicopter (Bell 205); 2 hrs/trip
- suitable ship transport to site for 4 trips (Government operated vessels may be available)
- accommodation (two people) in Tuktoyaktuk for 24 days (average of 3 days/trip)
- air fares: Victoria-Tuktoyaktuk return (8 trips)

Development Requirements - Approximately two months of development time by Frozen Sea Research Group (FSRG) will be required in order to make the technique operational.

Funds Required - To prepare: none

To implement:	Helicopter	$ 6,400
	Accommodation	$ 3,200
	Air fares	$ 4,700
	Air freight	$ 1,100
	Native assistant	$ 600
	TOTAL	$16,000

FSRG does not have a side-scan sonar but other government departments do (Defence Research Establishment-Pacific Region, Victoria; Energy Mines and Resources, Ottawa). Considering the cost of this device (≈$35,000) and the limited use that would be made of one in this study, the purchase of one for this study is not warranted. Prior arrangements could presumably be made with another government department for use of a side-scan sonar.

Relationship to Other Studies - This study would be complemented by results from the study 1A Remote Sensing.

4. Deposition and Decomposition of Spilled Oil

Two of the more important questions concerning an oil spill in the Arctic are how much oil is likely to be deposited in various habitats, and how quickly does the oil decompose in these habitats. Oil does not disperse uniformly through the marine environment but tends to concentrate in different amounts in different areas. Moreover, the initial areas of deposition are often not the final areas of concentration.

The habitats likely to prove most vulnerable to oil intrusion during or immediately after a spill include the surface of the water, the water column, the ice, the bottom areas in zones of high sediment deposition, and the coastal areas (open shorelines, coastal embayments, and inland areas flooded during storm surges). In the event of an oil spill in the Beaufort Sea, assessments of the fate of the oil and of the ecological damage caused by the oil will depend on both a knowledge of the maximum concentrations or quantities of oil that intrude into the various habitats and a knowledge of the extent of the affected areas. Quality (i.e. physical dissolved forms, coarsely dispersed, finely dispersed, adsorbed on sediments, intact on beaches) and composition of the oil will be as important factors as is the quantity in influencing toxicity. Both should be assessed as part of the overall sampling program.

4A. Oil in the Water Column

The major impacts of the oil that is dissolved or dispersed in the water column will be on plankton, on the egg and larval stages of fish, and to a

lesser extent on adult fish. The extent of these effects has usually been inferred from laboratory toxicity experiments (see study 5) due to the difficulty in detecting such effects in the field (see studies 6, 7 and 8). The relationship of the experimental conditions to the actual field conditions, however, is not well known - largely because measurement of the quantity and quality of oil present in the water column has been and continues to be one of the most difficult studies to carry out in any detail during an oil spill. In particular, oil contamination of the sampling gear is a major problem because it results in contamination of water samples.

Objectives

To determine concentrations, composition, and quality of oil present in the water column.

Methods - If a suitable sampling platform is available after an offshore oil well blowout during the open-water period, water samples could be obtained using Blumer samplers or sterile bag samplers. Samples could be obtained on several occasions from several depths and at various locations in the vicinity of a blowout. During winter, a similar series of water samples could be obtained through the ice. Preliminary processing of water samples for total hydrocarbon content (dissolved and dispersed) would be undertaken at a shore based laboratory, preferably in Tuktoyaktuk and final analyses could be completed in Victoria at the DFE Institute of Ocean Sciences, Ocean Chemistry Laboratory.

There are a great many problems associated with the determination of size and density of oil droplets in water samples. Particle size analysis can be undertaken using a Coulter counter. However, the Coulter counter cannot distinguish between oil and non-oil particles; consequently results

obtained with this technique may be of little value in the Beaufort Sea where levels of suspended matter are quite variable. Because oil droplets will tend to come out of suspension and adhere to the sides of the sample containers, it is necessary that these determinations be carried out soon after the sampling (preferably on the same day). This will present a problem if the oil spill is some distance offshore and the ship remains offshore for several days in succession. If the vessel is serviced by helicopter, the samples could be flown out in this manner. The Coulter counter could easily be placed on a large vessel, but ship vibrations possibly would seriously affect the operation of the counter.

The above methods will not provide a detailed quantitative record of the distribution, quantity, and quality of oil in the water column. They will, however, provide crude estimates of concentrations and quality of oil in the water column. This information will be of use to toxicity determinations, particularly when combined with measurements on salinity, temperature, and turbidity. It is also important that the studies 2B and 2C on subsurface currents be conducted in conjunction with this study.

A second method of measuring the hydrocarbons in the water column is presently in a hypothetical stage. If developed, it could provide a fairly detailed picture of the quantity and behaviour of the oil in the water column during oil spills in open water. A submersible towed-pump would pump water through a tubing system to a fluorometer on the ship where the relative fluorescence of samples could be immediately measured. The system would be calibrated by tapping off samples directly after fluorescence measurements and later conducting hydrocarbon extraction procedures at a shore-based laboratory and using a Coulter counter to obtain information on the sizes and

concentrations of droplets. A similar system is already in existence for hydrocarbons of low molecular weight.

Timing of Study - Open-water period and winter period.

Criteria for Initiation - Ideally, any major spill should be responded to; in practice, only oil well blowouts are likely to present any opportunities to carry out this study. An oil spill from a ship or pipeline is a relatively short-lived event, and it is probable that the study could not be initiated sufficiently quickly. A blowout would be a long-term occurrence and would provide sufficient time to mobilize and conduct the study and thus obtain useful data.

Government Agency and Project Leader

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Personnel Requirements - A chemist, experienced in sampling for hydrocarbons, and a chemical technician would be required to collect the data during the period of open water and during the winter, to conduct the laboratory analyses, and to summarize the results.

Equipment Requirements

Blumer sampler plus 20 bottle inserts

Sterile bag sampler system

Coulter counter (available in Victoria)

Field laboratory kit for hydrocarbon extraction and analysis

Ice auger

Logistic Support

- a ship with a suitable positioning system
- 20 hours of helicopter time for winter sampling
- laboratory space with power and adequate ventilation, preferably at Tuktoyaktuk or Inuvik
- airfare - Victoria-Tuktoyaktuk-return (8 trips)
- accommodation at Tuktoyaktuk for 2 persons for three months open-water period, 3 months winter

Funds Required - To prepare:	Blumer system	$6,000
	Sterile bag sampler system	$1,500
	Field chemistry equipment	$2,500
	Total to prepare	$10,000
- To implement:	Helicopter (Bell 205)	$16,000
	Laboratory supplies	1,100
	Airfare	4,700
	Airfreight	1,000
	Accommodation	23,200
	Total to implement	$46,000
	TOTAL	$56,000

Priority - Third Level

The implementation of this study is important but the severe logistical constraints at present on successfully conducting the study make it a third level priority study. Hydrocarbon analyses are also important components of several studies (4B, 4D, 6) that are of higher priority. Hydrocarbon sampling methods for these studies are probably more feasible logistically than for the situation described above.

Relationship to Other Studies - This study would be carried out in conjunction with studies 2B and 2C on sub-surface currents. The results of studies 1A Remote Sensing, 1C Radio Tracking of Oil Under Ice, 4C Oil in Sediment-Laden Waters, and 4D Chemical Weathering of Oil would assist in the interpretation of the results of this study. The results of this study will be useful to the interpretation of studies 4E Microbial Decomposition of Oil, 7 Effects of Oil on Under-Ice Flora and Fauna, and 8 Effects of Oil on Plankton and Fish Populations.

4B. Oil in the Coastal Zone

For the purposes of this study, the coastal zone has been defined as the portion of the coast extending from the 10 m depth contour inland to the highest storm surge level.

In the event of a major oil spill in the Beaufort Sea, the quantities of oil deposited along the shore or inland and the extent of the area affected will depend on winds, currents, and the type of spill (i.e. oil well blowout, tanker accident, etc.). In the Beaufort Sea area, beaches have been classified according to five types - cliffs, sand beaches, shingle beaches,

tundra, and mudflats. Existing techniques for clean-up of beaches are likely to be feasible and effective only for sand beaches and to a limited extent for shingle beaches (Logan et al. 1976). In the case of the other types of beaches and also for inland areas, more damage (e.g. increased erosion) would probably result from trying to remove the oil than from leaving it. A combination of chemical weathering and sea action will be important on beaches to remove the visible evidence of oil contamination. In inland areas, particularly tundra and marshes, chemical weathering will be important in degrading the oil. It will be important, accordingly, to monitor the deposition of oil in the coastal zone, to determine the fate of such oil and to assess the effects of the oil on vegetation, particularly in marsh or tundra areas that are critical to nesting or staging water birds (e.g. snow geese).

Objectives

1) To trace the movement, the pattern of deposition, and the ultimate disposition of oil in the Beaufort Sea coastal zone.
2) To assess the effects of oil on vegetation in the coastal zone.
3) To assess the short- and long-term effects of clean-up operations on the land forms of the coastal zone.
4) To determine the rate of weathering of oil that is left along the beach or on inland areas.

Methods - This study represents the initial phase of a long-term study. The methods described below are those required for the first year.

Whenever remote sensing (study 1A) indicates that oil is being deposited on a section of coastline, a further remote sensing survey would be carried out to record the length of shoreline contaminated and the extent of contamination.

Oblique aerial photographs (in colour)* would be obtained during this survey. If an extensive length of shoreline or inland area were impacted by oil, a photo reconnaissance flight by a CCRS aircraft would be made to obtain detailed photo records of the affected area. The IR (infra-red) capabilities of CCRS aircraft would provide useful information on both oil distribution and vegetation.

Five or more sample sites would be established as beaches or inland areas become oiled. Sites would be established in different beach and habitat types and according to different conditions applying to the beaches (i.e. whether or not the beach was to be cleaned up, degree of oiling).

Sites would be surveyed immediately after selection (where applicable, preferably before clean-up). Initial surveys of each site would involve vegetation mapping, sampling of beach sediments, and description and sampling of deposited oil. As soon as possible after these initial surveys, the following additional sampling would be carried out: comparative studies of bordering areas unaffected by oil; monitoring of beach processes, sediment movement and the incorporation or alteration of oil; and sampling from a boat of the bottom sediments offshore from the sites in order to determine the presence of hydrocarbons. Samples of oil on the beach would probably be obtained from sites at monthly intervals until freeze-up and snow cover occurred.

In the event of clean-up activities, a storm surge, or further

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* and/or in false colour

deposition of oil, the sites would be resurveyed immediately after the event. On a long-term basis the sites would be revisited at one year intervals to obtain information on geotechnical and vegetative changes. The frequency necessary for taking oil samples in successive years would be dependent on the rate of weathering of the oil as suggested by the studies during the first year.

Timing of Study - The study would be carried out when oil reached the coastal zone, which would occur only during the open-water period. In the event that the spill occurred after the start of freeze-up, the study would probably not be required until the following open-water period.

Criteria for Initiation - This study would be initiated immediately after the deposition of any significant quantities of oil in the coastal zone.

Government Agency and Project Leader

(For Geology)

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(For Oil Analyses)

- Dr. C.S. Wong
  Ocean Chemistry Division
  Institute of Ocean Sciences
  Department of Fisheries & Environment

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9860 W. Saanich Road

Sidney, B.C. V8Z 4B2

(For Remote Sensing)

- Allen R. Milne

Head, Arctic Marine Science

Ocean & Aquatic Sciences

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(For Vegetation)

- Agency: To be designated

Personnel Requirements - For the coastal zone surveys, a botanist, a geologist, and a geological technician would be required. The sediment sampling offshore would require a sedimentologist, a chemist, one assistant and a coxswain. The chemist would be required to provide instructions for the collection of oil samples, to assist in the sampling of sediments for hydrocarbon analysis, and to analyze oil and sediment samples. Depending on the number of samples taken, a considerable amount of time could be required in Victoria for laboratory analysis of samples. The botanist, chemist, and geologist would be required for report preparation.

Equipment Requirements

Onhand in readiness: sample containers used in collecting oil for analysis

samplers for nearshore bottom sediments (Petersen's grab sampler; pipe dredge; small shipek sampler)

Beach profiling equipment (available from EMR Dartmouth)

Laboratory equipment for analyses of oil and sediment samples (available at Ocean Chemistry Labs (DFE), Victoria)

Logistic Support

- 10 hr helicopter (Bell 205)
- 10 hr helicopter (Bell 206)
- small nearshore vessel (presently available at Polar Continental Shelf, Tuktoyaktuk)
- 2 hr CCRS aircraft (estimated)
- accommodation at Tuktoyaktuk for one month for six people and for two weeks for three others
- air fare: Halifax-Tuktoyaktuk-return (5 trips)
- air fare: Victoria-Tuktoyaktuk-return (1 trip)
- air freight: Halifax-Tuktoyaktuk

Funds Required -			
To prepare:	sampling equipment (dredges, etc.)		$1,500
	sample containers		500
	TOTAL to prepare		$2,000
To implement:	Helicopter		$11,500

CCRS or other aircraft	included in Study 1A
Laboratory supplies (estimated)	$ 1,000
Accommodation	14,500
Air fare	5,100
Air freight	3,400
Miscellaneous	2,500
TOTAL to implement	$38,000
TOTAL	$40,000

The logistic support and funds required have been calculated on the assumption of one major oiling of a coastal area with five sample sites being established following this oiling. The funds required will increase if oilings of beaches are more frequent or repeated, if more sample sites are established, or if the sample sites are established at different times.

Priority - Second Level

Relationship to Other Studies - This study would be a prerequisite to a long-term study on the ultimate fate of spilled oil in Arctic coastal areas. It will be important in interpreting the significance of results from the studies on the effect of oil on the coastal ecosystem (6), on the effects of oil on moulting sea ducks (9B), and on the effects of storm surges on birds (9D). Studies 4E (microbiology), 6 (coastal ecosystem study), and 9D (studies of bird mortality caused by a storm surge) could be combined with portions of this study (e.g. selecting same study sites, utilizing same aircraft, etc.).

4C. Oil in Sediment-Laden Waters

It is known that suspended sediment particles will adsorb oil and carry it to the bottom (Kolpack 1971:342). In the Beaufort Sea, however, it is not known how much oil is likely to be carried to the bottom via this mechanism in the Mackenzie River plume. The rate at which oil is blown across the plume area will probably determine both the amount that is carried to the bottom by sediment particles and the amount that crosses the plume and reaches shore.

In order to understand the behaviour and the impact of oil spills in the Beaufort Sea, it would be useful to sample suspended matter and bottom sediments immediately after and, if possible, during the movement of oil through the river plume area. Aerial and satellite photographs of the process would also be useful. Information on the initial location, composition, and quantity of oil deposited on the bottom would be required in order to interpret the long-term fate of the oil released from a spill.

Objectives

1) To assess the significance of suspended matter in removing oil from the water surface.

2) To determine the immediate fate of oiled particles (i.e. do they settle rapidly to the bottom or do they float for some distance before reaching the bottom).

Methods - Water samples would be taken at various depths and locations in the river plume after and, if possible, during the movement of oil across the plume. The particles in the samples would be examined for adsorbed oil, and samples would be analyzed for total oil content. Different types of

particles (e.g. clay, silt, etc.) settle at different rates; the types of particles adsorbing the oil will thus determine where the oil is deposited. Bottom samples from various locations across the plume would be collected and analyzed for oil content with respect to depth in the bottom layer. Nearshore work (to the 10 m contour line) would be done with a small vessel; offshore work would require a larger vessel.

Delineation of the initial settling locations of oiled particles would be necessary for the interpretation of the long-term fate of oil in the Beaufort Sea (i.e. how much oiled sediment is remobilized and deposited elsewhere and when this occurs). The long-term program would involve a yearly repetition of the bottom sampling program.

Information from the Remote Sensing study on the location and movement of oil in the river plume (1A), and on the movement of oil-tracking buoys (1B) and current drogues (2A) would be important to the determination of sampling strategy. The number of samples that are taken would probably be determined by the restrictions on the number that can reasonably be analyzed for hydrocarbons.

Timing of Study - The study would be carried out during the open-water period. It would probably require approximately two weeks of field time during and after the movement of oil into the area of the river plume. Long-term follow-up studies should be conducted during the open-water period in subsequent years.

Criteria for Initiation - The study would be initiated only if extensive oil slicks were blown into the river plume area. Initiation would depend on the availability of suitable vessels.

Government Agency and Project Leader

(Suspended matter)

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(Hydrocarbon analysis)

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  Department of Fisheries & Environment
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Personnel Requirements - A sedimentologist and two assistants, a chemist, and an assistant to the chemist would be required for nearshore field work. Depending on the number of samples taken, the analysis of the samples for hydrocarbons could require considerable time from the chemist and assistant. It would presumably be carried out in Victoria at the Ocean Chemistry Labs (DFE). The sedimentologist and chemist would be required for report preparation.

Because offshore work would require a large ship, more people, and a lead time of at least a month, it is unlikely that the study could be

carried out as part of the scientific response plan. The description of the equipment and logistic requirements given below is for the nearshore situation.

Equipment Requirements

Onhand in readiness:

- Shipek grab sampler
- benthos gravity corer
- teflon bucket
- sub-surface Niskin bottle
- vacuum pump flask
- portable STD and O_2 probe
- microscope (all of the above are probably already on hand)
- pipe dredges

Logistic Support

- 40 foot shallow draft vessel with positioning system
- facilities for chemical analysis of oil (Victoria)
- accommodation at Tuktoyaktuk for one month (5 people)
- air fare: Ottawa-Tuktoyaktuk-return (3 fares)
- air fare: Victoria-Tuktoyaktuk-return (2 fares)
- air freight: Ottawa-Tuktoyaktuk (2 ways)
- air freitht: Victoria-Tuktoyaktuk (2 ways)

Funds Required -	To prepare:	sampling equipment (dredges)	$ 500
		TOTAL to prepare	$ 500
	To implement:	Accommodation	$9,800
		Air fare	3,500
		Air freight	1,700
		TOTAL to implement	$15,000
		TOTAL	$15,500

Priority - Third Level

The results of this study would be important to the interpretation of the long-term fate of oiled sediment. The ultimate fate of oiled sediment will determine the biological recovery rate of an area extensively affected by oil. However, the results of this study may not be generally applicable to other parts of the Arctic where there are no major river deltas. Because of this aspect and because of the major logistical requirements, this study has been considered a third level priority.

Relationship to Other Studies - A meaningful conduct of this study would require detailed information from 1A Remote Sensing and would be greatly assisted by studies 1B Radio Tracking of Surface Oil, 2A Effects of Surface Currents and Wind, 4A Oil in the Water Column, and 4B Oil in the Coastal Zone. The results of this study, when combined with those from the study on the Effects of Oil on Coastal Ecosystems (6), would permit some assessment of the probable impact of the spill on the relatively scarce benthic fauna of the river plume.

4D. Chemical Weathering of Oil

Chemical weathering of spilled oil refers to the chemical alteration of oil by the environment and includes the following processes: dissolution, evaporation, photo-oxidation, and biodegradation. Dissolution and evaporation are the most rapid processes; they involve only the lighter, more volatile compounds. (Approximately 27% by weight of Norman Wells crude (a relatively light oil) spilled on a freshwater pond with a water temperature of 0 C had weathered within 24 hours (Scott 1975; cited in

Bunch and Harland (1976).) The portion of spilled oil that evaporates or dissolves and the rate of evaporation will generally depend on the composition of the oil and on the ambient temperature and water temperature. Biodegradation (see study 4E) and photo-oxidation are relatively slow processes that involve the heavier components. The heaviest components will remain as residues in the ecosystem; in temperate waters they commonly occur as 'tar balls'.

Objective

To determine the rate of chemical weathering of spilled oil under various environmental conditions.

Methods - In order to determine the rate of chemical weathering it is necessary to analyse the hydrocarbon content of the oil initially when it enters the water and again at later dates. By a comparison of the hydrocarbon components in the samples it is possible to determine the rate of weathering.

In order to determine the evaporation and dissolution rates for the more volatile portions of the spilled oil, it will be necessary to sample freshly released oil and to continue sampling the same oil at appropriate intervals over several days. During the open-water period, oil-tracking buoys will provide a convenient means of marking the oil being sampled and ensuring that the same oil mass is being sampled repeatedly.

During the winter, it will be logistically more difficult to obtain a series of samples of the same oil mass. In the event of a blowout in the transition zone, samples could be taken of oil in leads at or near the blowout, and in leads at varying distances from the blowout. The tracking of ice (study 1C) will provide an estimated age for the oil. Oil deposited

on the ice surface could also be marked (with radio buoys) and sampled at convenient intervals. Through use of ice corers, oil in or under various types of ice could be sampled. Oil could also be sampled when it migrated to the ice surface in spring. Oil samples obtained from the ice or leads during the winter would be examined to determine the degree and rate of chemical weathering.

The sampling of oils deposited on beaches and in sediments has already been described as parts of other studies (see 4B, 4C and 6). The analysis of the hydrocarbon content of these samples when first deposited and at later dates would give the rates of photo-oxidation and biodegradation.

Timing of Study - Throughout the year, depending on the type of spill.

Criteria for Initiation - Any oil spill and particularly one of crude oil.

Government Agency and Project Leader

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Personnel Requirements - A chemist would be required to carry out the sampling program. The analyses of samples, which would be conducted in Victoria, would require the services of a technician (under the supervision of a chemist). A chemist would be required for the interpretation and write-up of the hydrocarbon analyses.

Equipment Requirements

In Readiness: sample containers
SIPRE corer
laboratory equipment for hydrocarbon analyses (available in Victoria)

Logistic Support

- deep water vessel (open-water period offshore)
- nearshore vessel (open-water period)
- 15 hr helicopter (Bell 206) for winter use; this could easily be combined with other winter studies
- freezer facilities on the ship (for offshore) and in Tuktoyaktuk
- accommodation in Tuktoyaktuk for 6 months (one man)
- air fare: Victoria-Tuktoyaktuk-return (4 fares)
- air freight

Funds Required - To prepare:	sample containers	$ 500
	SIPRE corer (estimated)	2,500
	TOTAL to prepare	$3,000
To implement:	Helicopter	5,300
	Accommodation	11,700
	Air fare	2,400
	Air freight	1,000
	TOTAL to implement	$20,400
	TOTAL	$23,400

Priority - Second Level

Relationship to Other Studies - This study would be carried out in conjunction with studies on the movement of oil (1A, 1B, 1C). The results

of this study would assist in the interpretation of studies on coastal ecosystems (6) and under-ice flora and fauna (7).

4E. Microbial Decomposition of Oil

The rate of biodegradation of oil spilled in Arctic marine environments is of considerable interest; it is also an area for which little information is available. Marine microbial flora capable of the degradation of hydrocarbons are present in the Beaufort Sea (Bunch and Harland 1976), but it is not known with certainty how rapidly this flora will respond to an influx of petroleum - particularly at low temperatures. As a best guess, major changes in the composition of the flora might be expected within two weeks (at 5°C) provided the spilled petroleum remains with the same water mass. In the Beaufort Sea, however, temperatures lower than 5°C can be expected. Physiological changes in the flora existing at the time of the spill might be expected within several days of the event.

Objectives

1) To measure the rate of change in the composition of marine microbial flora present in the immediate area affected by a spill.
2) To measure the rate of physiological change in the microbial flora exposed to a spill.
3) To relate these changes to the rate of microbial decomposition of oil.

Methods - By means of Niskin S.S.1.5 bag samplers, water should be collected from immediately under surface oil and, as a control, from an area

adjacent to the spill. Sample water must remain chilled and must be processed at a land-based facility within eight hours. Similar sampling, preferably of the same oil mass should be repeated at monthly intervals or, as is more likely to be the case, until the spill disperses or reaches the shoreline.

The most useful information would be obtained by long-term site-specific sampling in the event of the spill reaching a semi-enclosed bay. An amount of petroleum can be expected to remain in the bay after clean-up efforts, and sampling in such a bay should be continued at 4-6 month intervals for 2-4 years.

The following microbiological laboratory procedures should be conducted with the sample water within 8 hours:

1) total viable count of bacteria on an appropriate plating medium,
2) total direct count by epifluorescence,
3) total numbers of oleoclastic bacteria by the most probable number procedure,
4) heterotrophic potential of flora using radiolabelled glutamate and/or acetate as substrates,
5) rate of CO_2 evolution from radiolabelled petroleum incubated with sample water.

Determination of nutrients, temperature, salinity, oxygen, and particulate and dissolved carbon should be made as part of the microbiological research. Of greatest importance is the long-term determination of various hydrocarbon fractions in the water column (4A), in sediments (4C), and on beaches (4B).

Timing of Study - Open-water period.

Criteria for Initiation - Any oil spill.

Government Agency and Project Leader

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Personnel Requirements - A microbiologist and a technician would be required to conduct this study. Each sampling session would require one day in the field, followed by a seven-day processing of the samples in Inuvik and a sixty day processing at the Arctic Biological Station.

Equipment Requirements

On site in readiness: Laboratory equipment at Inuvik Research Laboratory

On hand elsewhere: all necessary scientific equipment (samplers, incubators, microscope equipped for epifluorescence, liquid scintillator, etc.) is presently available at the Arctic Biological Station

Logistic Support - (per sampling session)

- use of facilities in the Inuvik Research Laboratory
- vessel for offshore work
- 4 hr helicopter (Bell 206)
- air fare: Montreal-Inuvik (2 fares)
- air fare: Inuvik-Tuktoyaktuk (4 fares)

- air freight: Montreal-Inuvik
- accommodation in Inuvik for 2 weeks (2 people)

Funds Required - To prepare: none

To implement:

Helicopter	$1,400
Water analysis (estimated)	800
Air fare	1,750
Air freight	700
Accommodation	1,850
TOTAL	$6,500

Priority - Second Level

Relationship to Other Studies - Meaningfulness of sampling during this study will be greatly enhanced if this study is conducted in close cooperation with studies 1A Remote Sensing and 1B Radio Tracking of Surface Oil. The results of studies 4A Oil in the Water Column and 4D Chemical Weathering of Oil will assist the interpretation of the results of this study. Results of this study will be of use to the study on coastal ecosystems (6).

5. Toxicity of Spilled Oil

Crude oils from different sources can vary widely in their toxicities - a consequence of the great variations in physical properties and chemical composition of the crude oils. One of the major uncertainties in predicting the general ecological consequences of a major blowout in the Beaufort Sea arises from the fact that the toxicity of the oil likely to be encountered is unknown. There is also no indication of the toxicity of the oil when it is mixed with the type of dispersants that could be employed in the area.

In order to assess the degree of risk associated with various clean-up operations it would be very valuable to have such information available.

Although this study is described as part of the scientific response plan it should be emphasized that this study could be most effectively undertaken following the discovery of oil under the Beaufort Sea (i.e. now) and before a major accident. It would be far easier to implement an invertebrate toxicity study if the timing of the experiment were determined by the investigator rather than by chance.

Objectives

1) To assess the toxicity of oil from a spill.

2) To assess the toxicity of oil-dispersant mixtures.

3) To assess the reaction of test organisms to various concentrations of oil and oil-dispersant mixtures.

Methods - The toxicities of crude oil and of various oil-dispersant mixtures would be tested at various degrees of dilution. A variety of techniques are available for this testing; each has advantages and disadvantages in particular situations. The ideal method is to employ a flow-through exposure system with automatic dilutors. However, the technical difficulties involved in dealing with unstable dispersions in such a system do not make this technique an attractive method for routine bioassays. A static system of the type outlined in La Roche et al. (1970) will probably be adequate for present purposes.

"Instant Ocean Synthetic Seawater" can be utilized for maintaining many arctic species (J. Percy, pers. comm.). It is produced by a reputable supplier, has been very widely used in a broad range of toxicity studies (it is a more stable, reproducible, and uncontaminated medium than the natural

seawater in many localities), and comes ready mixed in standard packages that simply require dissolving in tap water. A few of the Aquarium System refrigerated aquaria would also be useful for holding stocks of the animals in the laboratory prior to testing.

The methods that would be employed in this study involve monitoring the exposure groups at frequent intervals and determining the time of death (in contrast to La Roche's method of measuring the mortality after a fixed time interval). From these data the time required for 50% mortality at a given oil concentration can readily be calculated. Plotting the results for several concentrations will provide an estimate of the incipient lethal level.

The fact that the organisms of concern are from a low temperature environment demands that the tests be carried out in a refrigerated incubator in order that ambient temperatures for organisms can be duplicated.

Selection of test species for evaluating toxicity of the oil is difficult. One approach (and perhaps the best) would be to choose a few of the species (depending upon availability at the time - some are very seasonal in abundance) designated as relatively sensitive in the Beaufort Sea Project Technical Report No.11 (Percy and Mullin 1975). The amphipod Onisimus affinis is probably a good candidate because it is reasonably sensitive to oil, survives well in captivity, and is available year round in large numbers (in localized areas). Another approach would be to use invertebrates that are key food organisms and/or the most sensitive developmental stages of invertebrates (e.g. eggs, larvae, brooding female amphipods).

Fluorimetric methods (Percy & Mullin, 1975) would be used for estimating the concentrations of dispersed oil used in the bioassays. A fluorometer is presently available at the Arctic Biological Station.

The interpretation of the results of the toxicity experiments would be greatly aided if avoidance/preference experiments were also conducted as part of this study; especially the monitoring of the reactions of benthic invertebrates to oil-contaminated sediments. This would be useful information in connection with the decision to use or not to use "sinkants" for removal of oil from the water and would also prove useful for interpreting the results of benthic impact surveys. Standard procedures would be used to test the reactions of selected benthic organisms to sediments contaiminated with varying quantities of crude oil.

Timing of Study - Three to five months starting immediately after the spill (or preferably upon discovery of oil in the Beaufort Sea).

Criteria for Initiation - Any major oil spill.

Government Agency and Project Leader

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Personnel Requirements - Two full time trained technicians should be adequate for collecting and maintaining test organisms, preparing and measuring test concentrations of oil dispersions, conducting toxicity bioassays, and undertaking avoidance/preference tests. Study design, data analysis, and interpretation of results would require a research scientist experienced in conducting toxicity studies and avoidance/preference experiments.

Equipment Requirements

- refrigerated incubators (2)
- refrigerated aquaria (3)
- synthetic sea salts (10 boxes)
- reciprocating shaker (available at ABS)
- air pumps
- laboratory glassware
- avoidance/preference apparatus
- collecting gear (available at ABS)
- fluorometer (available at ABS)
- general laboratory supplies
- filters-fibrewound, carbon core

Logistic Support

- 10 hr helicopter time (Bell 206)
- laboratory facilities in Inuvik (preferably at the Inuvik Research Laboratory) with bench space, running freshwater, electrical power, etc.
- collection of test organisms would be carried out in conjunction with other studies. Sporadic short term use of divers (on an opportunity basis) might facilitate the collection of some species of test organisms.
- air fare: Montreal-Inuvik-return (9 fares).
- accommodation in Inuvik for 5 months (2 persons).
- air freight

Funds Required - To prepare:	incubators	$ 3,000
	aquaria	2,600
	salts	500
	filters, etc.	500
	laboratory supplies	2,400
	TOTAL to prepare	$ 9,000
To implement:	Helicopter	3,500
	Air fare	7,000
	Accommodation	19,500
	Air freight	2,000
	TOTAL to implement	$32,000
	TOTAL	$41,000

Priority - Second Level

Relationship to Other Studies - *Because of the implications of this study to the decision to use dispersants in countermeasures planning (cf. O'Rourke 1977) toxicity studies should be initiated for each type of crude oil that is discovered in the Beaufort Sea. These studies should be initiated prior to any spill of the oil.*

The results of this study will be important to the interpretation of the results from the studies on the effects of oil on coastal ecosystems (6), on under-ice flora and fauna (7), and on plankton and fish (8).

Should studies of this nature undertaken under the auspices of the AMOP and the EAMES(Eastern Arctic Marine Environmental Studies) programs prove to be adequate in addressing this question, this Study may be deleted from the Beaufort Sea Scientific Response Plan.

6. Effects of Oil on Coastal Ecosystems

Semi-enclosed embayments, lagoons, breached lakes, and shallow coastal waters are important to a variety of organisms, especially anadromous fish and some birds. Biologically, these areas may be the most vulnerable to oil spills in the Beaufort Sea (in the absence of an intertidal flora and fauna, which are strongly affected by oil spills in temperate waters). They may also be the areas that are contaminated most heavily because of the potential for large amounts of oil to be driven inshore and to concentrate in such regions. Entrapment of oil in the sediments of the coastal region may also occur; this entrapment is of particular interest because of the slow degradation of the oil in such a situation. It is consequently highly probable that the greatest impact, both short-term and long-term, of an oil spill will occur in coastal areas. This study then will be particularly important in assessing the biological impact of the spill. It may also serve as the starting point of a long-term study to determine the recovery rate of an impacted coastal area.

Objectives - To determine the fate and the biological impact of oil that reaches a coastal embayment.

Specifically, the objectives are to determine:

1) The amount of oil in the water column that is suspended, dissolved or adsorbed to particulate matter, the distribution of each with respect to depth, and the variation of each of these quantities with time;

2) The amount of oil being deposited into the sediments and the variation of this deposition with time;

3) The effect that the presence of oil in the sediment is having on the benthic invertebrate community structure;

4) The rate at which oil is being incorporated into selected invertebrate tissue;

5) The levels of oil that are being incorporated into fish tissue; and

6) The effect that oil is having both on biological oxygen demand (BOD) in the water and on primary productivity.

Methods - The scope and types of research that could be conducted in a study of this nature will be limited by the time of year during which the spill occurs, by the geographical area affected by the spill, and by the ability to predict the time and location of shoreline impact by the spilled oil. Under optimum circumstances, the following studies should be carried out.

Following the study site selection, a sampling program would, if possible, be initiated at four to six locations within the study area before the area is impacted by oil, and at four to six locations in a control area that will not be impacted. Sampling in the study area would be repeated immediately after impact. Sampling in a study area and in a control area should be performed even if the study area is impacted before sampling can begin and there is no information on pre-oiled conditions in the study area. The study of a control area will be necessary in order to distinguish between those changes in the oiled area that are natural changes and those that were caused by the oil.

Should it not be possible to select and sample control areas immediately prior to the impact of a coastal ecosystem, it may be possible to establish a pre-spill baseline by extrapolating from data collected during Fisheries Marine Service, Environmental Impact Assessment Division's study of the coastal habitats of the Tuktoyaktuk Peninsula, currently in progress.

It is anticipated that sampling after the impact by oil would take place in each area on a weekly basis for the first four weeks, biweekly for the next eight weeks, then at monthly intervals thereafter with a reduced level of sampling during winter. At each sampling location the following collections or analyses would be performed:

1) sampling of water and sediments for hydrocarbon analysis,
2) water sample profile including BOD analysis,
3) primary production estimates at intervals through the euphotic zone,
4) benthic invertebrate sampling for community structure analysis and hydrocarbon analysis, and
5) fish sampling for hydrocarbon analysis of tissue.

The sampling of the water and sediments for hydrocarbon analyses would be carried out by chemists, preferably in conjunction with other studies on hydrocarbons, but in full cooperation with the present research program. BOD and primary production measurements would be conducted using standard biological methods.

In sampling zoobenthos, both infauna and epifauna would be considered. Sampling of infauna would be conducted using a Petersen type grab. Enough samples would be taken at each station to sample about $0.25m^2$ of bottom.

Substrate from grabs should be washed through a 0.5mm screen and the retained invertebrates preserved in formalin. Samples would then be transported to the Freshwater Institute for processing. Sampling stations would be selected on a depth transect basis. Critical depths suggested are 2m, 4m, 8-10m, and the deepest part of the bay. If sampling can be conducted before the area is impacted by oil, 5-20 stations would be sampled for benthic infauna both before and immediately after the oil contamination. Sampling thereafter would only be required at 4-5 stations. Other parameters that would be measured are salinity, temperature of the water near the bottom, and substrate particle size.

Appraisal of the epifaunal contribution to the zoobenthos is more difficult because of sampling problems. Epifauna is rather sparse in the inshore waters of the Beaufort Sea and sessile species are extremely rare. The epifauna consists of mostly motile forms such as isopods, mysids, and amphipods. In the event of a spill, these motile animals may be able to escape from, or evade oil-contaminated areas, but there is also a possibility that they will be attracted to oil-contaminated areas.

Epifauna will be sampled by dredge or trawl, but data arising from such techniques are not always quantitatively reliable. Divers could possibly be of use in this project, but their vision may be impaired by turbidity of inshore waters, and the presence of oil could render diving difficult or impossible. Divers would cover bottom transects that were laid out in strips (1 m by 100 m) - a more quantitative collection method than the use of bottom trawls. Visual observations by qualified divers would also be useful for a more thorough knowledge of the distribution of oiled sediments, substrate types, and large species of epifauna.

The animal material selected for hydrocarbon analysis should consist of several different types of fish and invertebrate species. Animal material would be frozen on site and transported to Victoria for hydrocarbon analysis.

Waves and storm surges will be important factors in changing the amounts of hydrocarbons present in the water and sediments. Weather variables (temperature and wind) would be monitored at both sites. If available, temporary tide gauges would be installed.

This study is one that should be continued on a long-term basis in order to establish the recovery rate for impacted areas. The long-term study requires that very similar sampling stations be used from year to year (the exact same sampling site could not be used because of removal of organisms by previous sampling). During any particular year buoys could be used to mark stations but these would probably be moved by ice during spring melt. Triangulation from shore-based markers could be used to record and relocate sampling stations.

Timing of Study - Open water period and on a reduced level during winter. This study should be continued on a long-term basis in order to determine the rate of recovery of an area impacted by oil.

Criteria for Initiation - Any large oil spill that moves into a coastal embayment. It may be advantageous for the containment and recovery team to allow an oil spill to enter a coastal embayment so that the impact of the oiling may be studied by the scientific response team. This would be highly desirable in the event that a spill was threatening to enter a coastal system that had been previously studied by the Environmental Impact Assessment Division of Fisheries & Marine Service.

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Personnel Requirements - The biological portion of this study would require a marine invertebrate biologist, a technician, and an assistant for the field study. Two of these people should preferably be qualified divers. The biologist and technician would be required to carry out the identification of invertebrate samples, to analyze the data, and to prepare the report.

Sampling of water and sediments for hydrocarbon analysis would require a chemist and probably an assistant. These people would also be required to carry out the hydrocarbon analyses and summarize the results for incorporation into the overall report.

Equipment Requirements

In readiness:
- 16 ft. inflatable rubber boat
- 20-40 H.P. outboard motor
- Parcoll tent (12 x 16)
- generator (diesel 3-5 KW)
- heater
- miscellaneous sampling gear
- laboratory equipment for hydrocarbon analyses (available at Victoria)
- laboratory equipment for invertebrate identification (available in Winnipeg)
- salinometer
- light meter
- primary production apparati
- BOD analysis apparati
- tide gauge (available in Ottawa)

Logistic Support

- 10 hr helicopter (Bell 205) for camp establishment, or use available nearshore vessel (preferable)
- 30 hr helicopter (Bell 206) for servicing camp and transportation to and from area for chemist, or use available nearshore vessel (preferable) during open water and helicopter largely during winter.
- field camp costs (food, etc.)

- air fares: Winnipeg-Tuktoyaktuk-return (9 fares during open-water period; 18 fares during winter)
- air fares: Victoria-Tuktoyaktuk-return (4 fares during open-water period; 8 fares during winter)
- accommodation at Tuktoyaktuk (chemist and assistant) for three months

Funds Required - To prepare:	boat and motor	$ 5,500
	camp equipment	9,000
	sampling equipment	700
	traps and nets	500
	primary production apparati	1,000
	BOD analysis apparati	300
	miscellaneous	3,000
	TOTAL to prepare	$20,000
To implement:	Helicopter	18,500
	Air fares	27,500
	Accommodation	10,000
	Field camp subsistence	6,000
	Fuel: boats, generator, heater	2,000
	Sample & data analysis	10,000
	TOTAL to implement	$74,000
	TOTAL	$94,000

Priority - Second Level

If this study is pursued in sufficient detail, it will provide a sound basis on which to assess the recovery rate of an Arctic area impacted by oil. The results should be applicable to Arctic areas in general.

Relationship to Other Studies - The interpretation of results from this study will be assisted by those from studies on the Toxicity of Oil (5), Oil in the Coastal Zone (4B), the Behaviour of Oil in Sediment-laden Waters (4C), and on Chemical Weathering of Oil (4D). To reduce logistic costs this study should, wherever possible, be coordinated with studies 4E Microbial Decomposition of Oil and 4B Oil in the Coastal Zone.

7. Effects of Oil on Under-Ice Flora and Fauna

During late winter and early spring in Arctic Regions, an abundant assemblage of plants and animals, the epontic community, develops at and near the ice/water interface and within the ice itself. The overall importance of this community is not well understood. Primary production by epontic flora is substantial and serves as the base of a food chain that reaches to pelagic fish through one or two crustacean links, copepods and amphipods. Of the fish, the arctic cod, Boreogadus saida, is the most abundant pelagic marine species in many parts of the arctic seas and is a major food item of several predators including the ringed seal and the beluga whale. Arctic cod appear to be indirectly dependent for at least part of the year upon the under-ice community as the primary source of their food.

An oil spill under the ice could affect the flora in three ways:

1) The presence of oil in the ice could produce a shading effect on the ice flora below and inhibit photosynthesis.

2) Because oil released under the ice does not degrade, the volatile components, which are generally the most toxic, could inhibit primary production.

3) The oil could cause physical damage to the flora by directly coating it.

The direct effects of oil on the under-ice fauna, which feed on the flora, will probably be to exclude them from those portions of the under-ice surface that are covered by oil or that are affected by dissolved components of the oil. There may also be mortality due to coating of the fauna and due to the toxicity of components of the oil that are dissolved in the water.

Objectives

1) To compare the rate of primary production in oiled and unoiled ice.

2) To compare the densities of epontic invertebrates on under-ice surfaces in oiled and unoiled areas.

Methods - The major sampling effort during this study would be undertaken during the period of greatest growth of ice flora. Sampling would be carried out through the use of ice coring devices, under-ice net tows and through use of divers and underwater television.

Choice of sampling sites would be dependent on the extent of the oiled area. Ideally samples would be taken close to the point of maximum impact and at a series of points "downstream" of the spill. Control samples would

be taken close to but outside the spill area. Care would be taken to ensure that snow and ice conditions at the control sites were similar to those in the contaminated area.

A standard SIPRE corer would be used to obtain ice cores at the sampling sites. Parts of cores would be sectioned and melted and preserved for later microscopic examination and quantification of photosynthetic pigments.

Divers would be used to obtain samples from the under-surface of ice containing encapsulated oil or to obtain samples from the under-ice surface that is covered with oil by first removing the oil by some suction device. This latter technique would only be feasible for small pockets of oil. Sampling by divers would be undertaken in both oiled and control areas.

Under-ice photography, video-recording and descriptions based on visual observations of the under-ice conditions would fill important roles in this study. In addition to sampling the flora, divers would be able to study the rate of primary production using C_{14} techniques and to make observations on the densities and distributions of under-ice invertebrates and on the presence of arctic cod.

Timing of Study - Early March to June with the major effort concentrated in a 4-6 week period when growth of the flora is maximum.

Criteria for Initiation - Any major spillage of oil under the ice.

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(Project Leader)

- Dr. A.W. Mansfield, Head

(Research Scientists)

- Dr. Steven Hsiao

  Dr. E.H. Grainger

Personnel Requirements - A phytoplankton specialist would be required to conduct the field portion of this study, to identify the organisms in the samples, and to summarize the results. During the peak period of floral growth, divers and assistants would be required to conduct the under-ice sampling and observations. These people should have biological training. An invertebrate specialist would be required to assist in the field program, to carry out the identification of invertebrates, and to summarize the results obtained by the divers.

Equipment Requirements

In readiness:
- SIPRE corer
- field microscope (Arctic Biological Station)
- field support equipment
- ice camp and equipment

Equipment to be leased:
- underwater television camera and video recorder
- underwater still camera
- diver to surface communications system
- 300 watt electrical generator

Logistic Support

- 50 hours helicopter (Bell 206)
- 10 hours helicopter (Bell 205) for establishment and dismantling of ice camp

- accommodation at Tuktoyaktuk for 1 person for 5 months
- air fare: Montreal-Tuktoyaktuk-return (6 fares).
- air fare: divers (est. $2,000)

Funds Required - To prepare:	SIPRE corer	$2,500
	ice camp	5,500
	TOTAL to prepare	$8,000
To implement:	3 month lease underwater television system, Video tape recorder, communications system	10,000
	3 month lease of generator	800
	Helicopter (Bell 206)	17,500
	(Bell 205)	8,000
	Air fare	6,800
	Accommodation	9,800
	Ice Camp subsistence	15,000
	Air freight	2,100
	TOTAL to implement	$70,000
	TOTAL	$78,000

Priority - Second Level

Relationship to Other Studies - This study should be carried out in co-operation with studies on tracking oil under ice (1C), on the hydrocarbon levels in the water column under the ice (4A), on the weathering of hydrocarbons in and under the ice (4D), and on the under-ice currents in the vicinity of a blowout (2C). When the results of this study are combined with those from the studies on the quantity and distribution of oil on the ice surface (2D) and on the toxicity of oil (5), an assessment could be made of the overall effects of the spill both on primary production by the ice flora and on the fauna utilizing the flora.

8. Effects of Oil on Plankton and Fish Populations

'The probability of immediate major losses of fish from an oil spill or blow-out is expected to be low. High density semi-anadromous and marine pelagic and marine schooling species are mobile and would be expected to avoid or move out of oiled areas. Resident benthic species, except those in the immediate area of the spill, would be expected to respond to secondary effects of low level toxicity, reduced or contaminated food items. Sampling variability would make it difficult to detect significant differences between oiled and control areas over a short time period.

Oil in shallow bays and lagoons and on sand beaches will probably cause havoc among the larval fish and beach spawning species of the area. However, most have a wide geographical distribution such that re-population from adjacent unpolluted areas could follow. Only two or three species are likely to experience major hardships.

Plankton and the eggs and larval stages of fish are relatively non-mobile (compared to adult fish) and are thus susceptible to the toxic effects

of oil. Unfortunately, there are sampling problems associated with estimating their relative abundance because of their patchy distributions, their avoidance reactions to sampling gear, and the actual mechanics of sampling. In addition, sampling in oil-contaminated waters will probably result in clogging of plankton nets and matting of samples by oil. Despite these problems, there are some useful measurements that could be made.

On the basis of information on the density of plankton and of fish eggs and young-of-the-year in the general vicinity of the affected area, confirmation and distribution of oil in the water column, and of the toxicity of the oil, assessments can be made regarding the probable effects of the oil on the populations of plankton and fish eggs and young. Studies on the age structure of fish populations in subsequent years would indicate any major mortality of eggs or young during the year of the spill. They could not, however, establish that the mortality was due to the oil spill.

Objectives

1) To assess the densities of plankton and of fish eggs and larval and young of the year fish in the general vicinity of the spill during both summer and winter.
2) To collect plankton and fish specimens for hydrocarbon analysis.
3) To assess the probable impact of oil on plankton and on fish eggs and young.
4) To assess the impact of an oil spill on the density and disribution of adult and juvenile fish.

Methods - During the open-water period, plankton tows would be conducted in an area near and similar to the contaminated area in order to obtain density estimates for plankton and for fish eggs and young of the year. Tows would also be carried out in contaminated areas to obtain samples for hydro-

carbon analysis. Bottom and mid-water trawls would be made in contaminated and uncontaminated areas to obtain fish specimens for abundance and hydrocarbon analysis. Echo sounder surveys of both contaminated and uncontaminated areas would also be undertaken.

During winter, plankton would be sampled by making vertical tows from the ice surface. This would be carried out in conjunction with the under-ice flora and fauna study (7). If divers are employed in the under-ice study, they could obtain useful information on the reaction of adult arctic cod (if present) to oil present on the under-ice surface. Arctic cod would also be collected to test for hydrocarbons in the flesh and in the food organisms in the stomach.

Timing of Study - Open-water period, and March to May for ice studies.

Criteria for Initiation - This study would be conducted only in conjunction with other studies. During the open-water period, these studies would include the study on subsurface currents (2B) and the study on oil in the water column (4A). During the winter, these studies would include the study on under-ice flora and fauna (7) and the study on under-ice currents (2C). The laboratory study on the toxicity of the oil (5) would also be required.

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Personnel Requirements - The portion of the study conducted during the open-water period would require a biologist and two assistants (additional assistance required to conduct trawls and tows could come from other investigators present). The biologist would also be required to analyze and interpret plankton sample data. Preservation of samples for hydrocarbon analysis would be carried out by a chemist, who would be present for the study on oil in the water column (4A). An assistant to the chemist would be required to carry out the tissue analyses. The chemist would be required to interpret and summarize the results.

Equipment Requirements

In readiness: - bottom and mid-water trawls
- plankton nets

Logistic Support

- Deep water vessel (open-water season), to include accommodation for three researchers. Vessel would also support studies 4E, 5 and 7
- Helicopter support for the project would be shared with study number 7
- Accommodation at Tuktoyaktuk for 1 person for the duration of the study (up to 5 months)
- Airfare Montreal-Tuktoyaktuk (return) - to be shared with studies 4E, 5 and 7.

Funds Required - To prepare:	Mid-water and bottom trawls	$ 1,000
	TOTAL to prepare	$ 1,000
To implement:	Accommodation	9,800
	Field supplies	3,000
	Air freight	2,200
	TOTAL to implement	$15,000
	TOTAL	$16,000

Relationship to Other Studies - The implementation of this study would depend on the results of studies 1A and 1C on movement of oil and would only be carried out in conjunction with studies described previously in the criteria for initiation (2B, 2C, 4A and 7). The results of this study, when combined with those from the toxicity study (5), the study on oil in the water column (4A), and the study on coastal ecosystems (6), could be used to infer probable impacts of the oil spill on plankton and on fish eggs and young-of-the-year.

9. Effects of Oil on Water Birds

Water birds are particularly susceptible to oil spills. The oil mats the feathers, destroying their insulation and buoyant qualities. As a result the birds may succumb to the cold, they may sink and drown, or they may leave the water and consequently starve or be taken by predators. They may also succumb to the effects of preening and ingesting oil from their plumage.

Because of the obvious and frequently heavy mortality and because of the emotional attachment that many people have for birds, bird mortality

usually receives considerable attention from the news media. An oil spill in the Beaufort Sea will probably be no exception.

Methods of reducing bird mortality in the presence of spilled oil are the responsibility of those involved in countermeasures planning and are not addressed in this study. The studies described in this section are concerned only with assessing the extent of bird mortality from an oil spill.

9A. Bird Mortality During Spring Migration

During May and June, tens of thousands of water birds (predominantly eiders and Oldsquaw) are known to migrate into or through the Beaufort Sea area via coastal and offshore routes (Richardson et al. 1975; Searing et al. 1975). During this migration period these birds are dependent for resting and feeding on the presence of patches of open water, ice leads, and melt ponds in the transition zone (cf. Barry 1968). A major oil well blowout during May or June, particularly in the transition zone, could result in the presence of many oil-covered leads and of numerous pools of oil on the ice surface along the migration route of these birds. It is expected that migrant water birds would mistake these areas for open water and land in them (cf. Barry 1970; NORCOR 1975; Milne and Smiley 1976). The resulting mortality could be substantial.

Objectives

1) To determine the species and numbers of water birds that are killed as a result of the presence during spring of oil-contaminated ice and leads.
2) To determine the reactions of migrant birds to oil pools on the ice surface and to oil-covered leads.
3) To determine the extent of utilization of oiled birds by scavengers (e.g. arctic fox).

Methods - Helicopter surveys of oil-covered leads and of pools of surface oil within the contaminated area would be flown twice weekly. If numbers of oiled birds are able to move out of the oil onto the ice or into oil-free water it will be possible to survey them from the air. The helicopter will have to be landed frequently in order to determine numbers of birds actually in the oil (where they will be difficult to see), to identify heavily oiled birds, and to mark dead birds in order to determine both the rate of scavenging and the additional numbers of birds that had been killed.

On several occasions the observer would spend some time in a blind on the ice in the vicinity of oil-covered leads or surface pools of oil in order to study the reaction of flying (migrant) birds to the oil. The observer would record the species, flock sizes, direction and heights of flight, and behaviour with respect to the oil.

The specific methodology of the surveys will be determined by the extent of the contaminated area, the degree of success of attempts to burn the oil, and the ease with which oiled birds can be observed (if at all) from the air.

Timing of Study - May, June and July

Criteria for Initiation - Observations would be initiated if remote sensing indicated the presence of oil-covered leads or surface pools of oil during the spring migration period. Because of the apparent attraction that surface pools of oil and oil-covered leads could hold for water birds, it would be useful to conduct this study whenever any such areas occur. Limited observations suggest that even a few small pools of oil could cause considerable bird mortality (Barry 1970; NORCOR 1975). If only a small amount of oil were present, the study would be scaled down accordingly.

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Personnel Requirements - One (possibly two) experienced bird survey biologist(s) would be required to conduct surveys, to analyze and interpret the data, and to write up the report. He would be accompanied by a native assistant during all surveys on or over the ice.

Equipment Requirements

In Readiness:

- Arctic winter survival gear
- 2 tape recorders)
- spare batteries, tapes) already
- spotting telescope) on hand
- blind

Logistic Support

- 100 hrs of helicopter (Bell 206) (estimated)

- 2 months accommodation for two persons at Tuktoyaktuk (depending on location of spill).
- Air fare: Edmonton-Tuktoyaktuk-return (2 fares).
- Fuel caches at Komakuk, Sachs Harbour, Cape Parry, Summers Harbour, Cape Dalhousie and Shingle Point.

Funds Required - To prepare:	Nil	
TOTAL to prepare	Nil	
To implement:	Helicopter charter	$35,000
	Accommodation	8,000
	Native assistant	3,000
	Fuel caches	7,000
	Miscellaneous field equipment	1,000
	Air fare	1,000
	TOTAL to implement	$55,000
		$55,000

Priority - Second Level

Relationship to Other Studies - The implementation and the extent of this study will depend on information from the Remote Sensing Study (1A) and the Study on Ice Movement (1C). In the event of a very large contaminated area of ice, the results of the study recording the presence of Oil on the Ice Surface (2D) will be important to the interpretation of results from this study. The Study on the Effects of Oil on Whales During Spring (12A) would be conducted in conjunction with this study.

9B. Mortality of Moulting Sea Ducks

During July and August, tens of thousands of diving ducks (predominantly

scoters and Oldsquaw) are known to congregate along the Beaufort Sea coast, particularly in bays and lagoons, in order to undergo their annual wing moult (Searing et al. 1975). They are flightless at this time and are thus particularly vulnerable to oil spills. In the event of a major oil spill in the Beaufort Sea during this period, oil could be blown into coastal areas where it could cause substantial mortality to these birds.

Objectives

1) To determine the numbers, species, and distribution of water birds (particularly diving ducks) present in coastal areas before (if possible) and after an oil spill reaches these areas.
2) To determine the species and numbers of dead and oiled birds relative to the species and numbers of birds that could potentially have encountered the oil.
3) To assess the responses of the birds to the oil.
4) To determine the extent of utilization of the carcasses of oiled birds by scavengers (e.g. foxes, gulls).

Methods - Aerial surveys would be conducted of the coastline in threatened areas in order to establish the species, numbers and distribution of sea ducks both before (if possible) and after any oil reaches the threatened areas. These surveys would be designed to obtain total counts of birds in the coastal areas and would be initiated as soon as possible after the spill occurs. The surveys would be conducted at weekly intervals, particularly in those coastal areas where the threat of oil-contamination is high.

Ground surveys of the numbers of dead birds along beaches (beached bird surveys) would also be conducted immediately after the oil reaches the

coast and at weekly intervals thereafter. The following information would be recorded during the beached bird surveys: species, numbers, location, and condition of oiled birds; evidence of scavengers; and quantity and location of oil (e.g. on the beach, in the water, etc.). By marking dead birds during each beached bird survey (e.g. removing a wing) and by repeating the surveys, information could be obtained on the removal of dead birds by scavengers. Comparative information on normal mortality could be obtained by surveying a similar but uncontaminated area.

Timing of Study - Mid-July to mid-September.

Criteria for Initiation - This study would be initiated almost immediately after any major oil spill during July and August that would possibly result in oil reaching coastal areas.

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Personnel Requirements - Two biologists experienced in conducting aerial surveys of water birds and familiar with conducting beached bird surveys would

be required during the late summer if there were a threat of oil reaching coastal areas.

Equipment Requirements

On Site in Readiness - None.

On Hand Elswhere - tape recorders (2)

- spare batteries, tapes

Logistic Support

- 50 hr fixed wing aircraft (Cessna 337) for aerial surveys
- 30 hr helicopter (Bell 206) for transportation to survey sites for beached bird surveys. This could be done in conjunction with studies 4B or 6
- Accommodation for two months (two people) at Tuktoyaktuk
- Air fare: Edmonton-Tuktoyaktuk-return (4 fares)

Funds Required - To prepare: None

To implement:		
	Aircraft	$23,000
	Air fare	2,000
	Accommodation	8,000
	TOTAL	$33,000

Priority - Second Level

Relationship to Other Studies - The implementation of this study will depend on the results of the Remote Sensing Study (1A). The results of the studies on Oil in the Coastal Zone (4B) and on Effects of Oil on Coastal Ecosystems (6) will provide important information for interpreting the results of the aerial and beached bird surveys.

9C. Mortality of Birds in Offshore Open Waters

By the time of the open-water period in the southern Beaufort Sea (sometime in July), many (perhaps most) birds will have moved inland to nest. Those birds that remain on or return to the open water offshore will apparently occur in very low densities (Searing et al. 1975). It is also possible that clean-up activities during an oil spill will frighten birds away from the contaminated areas. The mortality to birds in offshore areas is thus expected to be small. Moreover, any offshore bird mortality due to oil will be difficult to measure because the birds may sink and because dead birds on the water are difficult to see both from aircraft and from ships (Hay 1976). An offshore study would thus be able to measure only the species and numbers of birds that were present in affected and unaffected areas. Little direct information could be obtained on actual bird mortality in these areas. A study is briefly described below for an offshore area but it is not considered a high priority study.

Objectives - To determine the species and numbers of water birds in oiled and unoiled offshore areas.

Methods - Standard aerial survey techniques for birds would be used to determine the species and numbers of birds on transects through the area affected by the oil spill and through adjacent unaffected areas. Surveys would be flown at weekly intervals during the open-water period for the duration of the spill. Comparisons of densities between the areas should indicate whether the birds are avoiding the contaminated area.

Timing of Study - Open-water period.

Criteria for Initiation - This study would only be considered if remote sensing observations indicated the presence of large numbers of water birds offshore in or near contaminated areas.

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Personnel Requirements - Two experienced aerial survey biologists would be required for this study.

Equipment Requirements

On Site in Readiness - None

On Hand Elsewhere - tape recorders (2)
- spare batteries, tapes (already on hand)

Logistic Support

- 60 hrs Cessna 337 with positioning system
- Accommodation for 1½ months at Tuktoyaktuk (two observers and pilot)
- Air fare: Edmonton-Tuktoyaktuk-return (4)

Funds Required - To prepare: None

To implement:

Aircraft charter	$13,500
Accommodation	8,700
Air fare	1,800
TOTAL	$24,000

Priority - Fourth Level

Relationship to Other Studies - The implementation and survey design of this study would depend on information obtained during the Remote Sensing Study (1A). The study would be conducted by the same personnel and at the same time as Study 9B Mortality to Moulting Sea Ducks.

9D. Effects of Storm Surges on Birds

Storm surges could carry oil inland to contaminate tundra, lakes, and delta areas, and could cause mortality to birds that nest or feed in these areas. Most major storm surges occur in late September or October when most birds have left the Beaufort Sea area. However, the occurrence of a storm surge in July or August, in combination with a major oil spill, could result in mortality to breeding birds, to young, or to staging or migrating birds that were present in the affected areas. It may be difficult, however, to assess directly the magnitude of any such mortality. Lightly oiled birds will probably hide in vegetation; heavily oiled dead birds will probably be mixed with oil or oiled vegetation where they will be difficult to see. Scavengers will probably remove some of the oiled birds.

Moulting birds and broods of water birds would be particularly sensitive to oil contamination because they are flightless and hence unable to escape from the oil. The mortality to these birds could be measured indirectly by conducting surveys in the contaminated area and in a similar control area. Comparisons between the two areas would provide a crude measure of the impact on young and on moulting birds.

A storm surge in late September or October will not directly affect birds, but oil deposited in nesting areas could create a problem for birds during the next breeding season. If a storm surge were to contaminate an

extensive area of nesting habitat, a study would be implemented the next year to determine the impact on nesting birds.

Objectives - To assess the impact on habitat, food and reproductive success of water birds and on moulting water birds from oil contamination caused by a storm surge.

Methods - Immediately after the storm surge aerial surveys by helicopter would be made of a portion of the contaminated area and of a similar control area in order to determine the number of broods, the number of moulting birds and the numbers of oiled birds visible. A second survey would be conducted one week later.

Timing of Study - July to early September.

Criteria for Initiation - Any storm surge that carried oil inland during the period from July to early September. After early September, the results of study 4B Oil in the Coastal Zone would be used to determine the need for a study during the nesting season of the next year.

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- Dr. T. W. Barry

Personnel Requirements - An experienced waterfowl biologist would be required to lead the study.

Equipment Requirements

On Site in Readiness - None

On Hand Elsewhere - tape recorders (2)

- batteries, tapes (already available)

Logistic Requirements

- 15 hrs helicopter (Bell 206)
- Accommodation in Tuktoyaktuk for 2 weeks (1 person)
- Air fare: Edmonton-Tuktoyaktuk-return (1 fare)

Funds Required - To prepare:		Nil
To implement:	Helicopter	$ 5,250
	Accommodation	900
	Air fare	450
	TOTAL	$ 6,600

Priority - Second Level

Relationship to Other Studies - The implementation of this study would depend on the results of study 1A Remote Sensing. The results of the study 4B on Oil in the Coastal Zone will be necessary for the interpretation of the results of this study.

10. Effects of Oil on Seals

During the open water season it is very probable that bearded and ringed seals (the two principal species of seals in the Beaufort Sea) will avoid any spills and will suffer little or no mortality as a result of the oil.

In the winter months the response and susceptability of seals to oil spills could be quite different. Bearded seals and subadult ringed seals tend to occur largely in the leads and polynias in the transition zone off the Tuktoyaktuk Peninsula and off Banks Island (Stirling et al. 1975b). Bearded seals also pup in these areas. If extensive areas of the transition zone are contaminated with oil (as suggested by Milne and Smiley 1976), these animals will possibly be incapable of avoiding the oil. Because winter is probably a very stressful period for seals, any prolonged contact with oil by seals could cause substantial mortality (cf. Smith and Geraci 1975).

During the winter a large portion of the adult ringed seal population occurs in the fast ice zone off the Tuktoyaktuk Peninsula, off Banks Island, and in the Amundsen Gulf. Pupping also occurs in these areas. Contamination of large portions of this habitat (considered to be highly unlikely) could have effects on the survival of both adult ringed seals and pups.

10A. Spring Distribution and Numbers of Seals

Objectives - To determine the numbers and distribution of bearded and ringed seals with respect to oil-contaminated and uncontaminated areas of the Beaufort Sea.

Methods - Aerial surveys along a transect grid would be conducted during the spring break-up period in the same manner as the surveys conducted before, during, and subsequent to the Beaufort Sea Study Project (Stirling et al 1975b).

Timing of Study - Approximately 1 June to 21 June.

Criteria for Initiation - This study would only be useful with respect to the effects of an oil spill on seals provided that extensive areas were contaminated with oil and provided that baseline studies had been conducted in the year previous to the spill.

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(Project Leader)

- Dr. Ian Stirling

Personnel Requirements - Two experienced marine mammal survey biologists would be required to conduct surveys, analyse the data, and prepare the report. During surveys these people would be accompanied by a native assistant familiar with survival and travel on the ice.

Equipment Requirements - Required equipment (tape recorders, etc.) is presently available.

Logistic Support

- 80 hr fixed-wing aircraft (Cessna 337) with positioning system
- fuel cache at Komakuk
- fuel cache at Sachs Harbour
- accommodation for two people
  1 week Inuvik
  1 week Tuktoyaktuk
  1 week Sachs Harbour
- air fares: Edmonton-Inuvik-return (2)

Fuel caches for this study should be established at the same time as those for the Polar Bear Study (11), since the criteria for implementation are similar for both studies.

Funds Required - To prepare:		Nil
To implement:	Aircraft	$18,000
	Fuel cache	2,500
	Accommodation	2,750
	Air fares	750
	Native assistant	1,000
	TOTAL	$25,000

Priority - Second Level

Relationship to Other Studies - The implementation of this study is highly dependent on the results of the Remote Sensing Study (1A) and the Ice-Tracking Study (1C). The interpretation of the results of this study will be aided by the results of the Polar Bear Survey (11), and of the study on the Effects of Oil on Seals in the Transition Zone (10C).

10B. Effects on Seals in the Fast Ice Zone

Objectives

1) To compare densities of ringed seal lairs in an oil-contaminated area with densities in a similar but uncontaminated area.

2) To record any oil contamination of lairs and of pups in birth lairs.

Methods - A helicopter would be used to reach offshore areas and an over-snow machine to reach nearshore areas. Seal lairs would be found through use of a trained dog, and by sight if the lair had been opened by a predator. Any oiled seal pups found dead would be necropsied to establish cause of death.

Timing of Study - Late March to early May.

Criteria for Initiation - Unless an extensive area of fast ice is oiled, it is unlikely that the data would meaningfully show any differences between oiled and unoiled areas. This study would, therefore, only be considered if an extensive area in the fast ice zone were contaminated with oil.

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- Dr. Thomas G. Smith, Arctic Biological Station

(Contract Pathologist)

- Dr. Joseph R. Geraci
  Department of Pathology
  University of Guelph
  Guelph, Ontario
  Telephone: (519) 824-4120 Ext. 3112

Personnel Requirements - One biologist and a native assistant would be required to carry out the lair searches. They would be accompanied by the pathologist in order to conduct field post-mortem examination of any dead seals encountered. The biologist and the pathologist would be required to analyze the data and prepare a report.

Equipment Requirements

Installation of locator beacon in the reconnaissance aircraft and a locator beacon on the ice.

Purchase of snowmobile and sled suitable for helicopter transport.

Other equipment in storage at Cape Parry.

Logistic Support

- 80 hrs helicopter (Bell 205) for offshore searches
- 5 hrs fixed-wing aircraft (Twin Otter) for transport of equipment from Cape Parry to Tuktoyaktuk
- Accommodation for 2 months at Tuktoyaktuk (2 people)
- Airfare: Montreal-Tuktoyaktuk-return (1)
  Toronto-Tuktoyaktuk-return (1)

Funds Required - To prepare:		Nil
To implement:	Helicopter charter	$64,000
	Aircraft charter	2,200
	Locator beacon & transmitter	1,700
	Snowmobile & sled	2,000
	Air fare	1,600
	Accommodation	8,000
	Native Assistant	3,000
	Contract Pathologist	5,000
	TOTAL	$87,500

Priority - Second Level

Relationship to Other Studies - The implementation of this study is dependent on knowing the extent of the contaminated area (1A). The interpretation of the results of this study would be greatly aided by a photo

record of oil when it comes to the surface in spring (2D), and by the results of the Polar Bear Study (11).

10C. Effects on Seals in the Transition Zone

Objectives - To compare the physical condition of seals in a contaminated area with that of seals in an oil-free area.

Methods - Seals would be collected at varying distances from the spill. They would be examined for external oiling and ingestion of oil and would be necropsied to determine their physical condition. During collecting trips, incidental observations would be made on seal behaviour.

Timing of Study - March and April.

Criteria for Initiation - As with the lair searches, this study would only yield sufficient quantitative data if an extensive area were contaminated with oil. It would only be undertaken if a blowout were to occur in the transition zone and if extensive areas of this zone were contaminated.

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Personnel Requirements - This study would require a biologist experienced in collecting seals, a pathologist, and probably two native assistants. The pathologist would be required to carry out the tissue analysis and to prepare the report.

Equipment Requirements - All equipment required for the field portion of this study is presently available at Cape Parry. Facilities and equipment for the preparation and examination of tissue samples are available at the University of Guelph.

Logistic Support

- 50 hr helicopter (Bell 205)
- transportation of field equipment from Cape Parry to Tuktoyaktuk (Twin Otter)
- air fare: Montreal-Tuktoyaktuk-return (1)
  Guelph-Tuktoyaktuk-return (1)
- accommodation for probably one month at Tuktoyaktuk (2 people)

Funds Required - To prepare:		Nil
To implement:	helicopter charter	$ 40,000
	aircraft charter	1,800
	air fare	1,600

accommodation	$ 4,000
native assistant	3,000
contract Pathologist	7,000
tissue preparation	600
TOTAL	$ 58,000

Priority - Third Level

Relationship to Other Studies - The implementation of this study will depend on the results of studies on the movement of oil under ice (1A, 1C). The results of this study will assist in the interpretation of the studies on the distribution and numbers of seals (10A) and of polar bears (11).

11. Effects of Oil on Polar Bears

Polar Bears are not randomly distributed over the winter ice of the Beaufort Sea. They tend to concentrate in ice habitats where seals are present and accessible (Stirling et al. 1975a). The three most important habitats, in approximate order of importance, are the following:

1) Areas in the transition zone where movement of ice caused by winds and sea currents has been followed by refreezing to create intermittent lanes or patches of refrozen young ice that are bare or only slightly drifted with snow.

2) Edges of large floes in the transition zone where there are large leads (1 km), small leads (open or refrozen), and pressure ridges that are not heavily drifted with snow.

3) Stable flat ice areas (in the fast ice zone) that are interspersed with pressure ridges that have not moved for a long time and that are drifted with snow suitable for seal lairs.

Oil contamination of an extensive area of these habitat types (particularly the first two) could substantially alter the numbers and distribution of seals and thus their accessability to polar bears. This could cause a decline in polar bear populations.

If the number of seals available to polar bears were to decrease substantially, there could be a noticeable increase in the number of dangerous encounters between polar bears and the men working on the Beaufort Sea ice.

Objectives

1) To assess the distribution of polar bears with respect to oil-contaminated areas.
2) To record the presence of any oiled bears and the degree of oiling.
3) To document circumstances surrounding man/bear encounters during and after an oil spill.

Methods - The same methods of surveying and tagging polar bears that were conducted before and during the Beaufort Sea Study Project (Sterling et al. 1975a) and that have been continued in 1976 should be repeated. A meaningful assessment of the effects of an oil spill on polar bear populations will be highly dependent on the conducting of baseline population studies in the year previous to the spill.

Timing of Study - Late March to mid-May.

Criteria for Initiation - This study would be conducted if extensive areas in the transition zone or the fast ice zone become contaminated with oil. The determination of whether the oiled area is extensive will depend on the ice zone, the location of the spill, and the relative amount of unoiled seal habitat available.

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- Dr. Ian Stirling

Personnel Requirements - Two experienced polar bear survey biologists would be required to conduct the surveys, to analyze data, and to prepare a report. These people should be accompanied by a native assistant familiar with survival and travel on ice.

Equipment Requirements - The equipment required (tranquilizer guns, tape recorders, winter survival gear, etc.) is already available.

Logistic Support

- 120 hr helicopter (Bell 206)
- accommodation for approximately two months at Tuktoyaktuk (2 people)
- Air fare: Edmonton-Tuktoyaktuk-return (2)
- Fuel caches at Komakuk and Sachs Harbour

Funds Required - To prepare:		Nil
To implement:	helicopter	$42,000
	fuel caches	12,000

accommodation	$ 8,000
native assistant	3,000
air fare	1,000
TOTAL	$66,000

Priority - Second Level

Relationship to Other Studies - Results of the studies on Radio Tracking of Oil Under Ice (1C) and Remote Sensing (1A) are critical to determining the need for this study. The results of the studies on the Effects of Oil on Seals (10A, 10B, 10C) would assist in the interpretation of the results from the study on polar bears.

12. Effects of Oil on Whales

12A. Effects on Whales During Spring

In May and June, bowhead and beluga whales migrate eastward into the Beaufort Sea, apparently along a network of leads and open water areas 200-300 km offshore in the transition zone (M. Fraker, pers. comm.). The destination of these whales during spring is the large open water area that forms in the southeastern Beaufort Sea (Amundsen Gulf) during May and June. Extensive oil contamination of leads and polynyas in the transition zone could delay the annual spring migration of bowheads and belugas into this area, if the animals were to avoid the oil rather than swim through it. The effects of such a delay on the whales are unknown.

Objectives - To monitor the migration behaviour of beluga and bowhead whales if oil-covered leads and polynias are present along their spring migration route.

Methods - This study would be combined with the study on the effects of oil on migratory birds (9A). Observations would be made both from the air and from the ice on the reactions and movements of whales through ice contaminated leads.

Timing of Study - Mid-May through late-June.

Criteria for Initiation - This study would be implemented only if extensive contamination of the transition zone were to occur along the migration route of the whales.

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(Contact)

- Dr. A. W. Mansfield, Head

(Project Leader)

- Dr. D. E. Sergeant

Personnel Requirements - A marine mammalogist would be required to carry out this study; he would accompany the avian biologist and native assistant. This person would also be required to analyze and summarize the results of the study.

Equipment Requirements - On Site in Readiness: None
On Hand Elsewhere: tape recorder, batteries, tapes

Logistic Support

- helicopter support provided by the study of mortality to migrating birds (9A)
- air fares: Montreal-Tuktoyaktuk-return (1)
- accommodation for 7 weeks (1 person)

Funds Required - To prepare:		Nil
To implement:	air fare	$ 800
	accommodation	3,200
	TOTAL	$4,000

Priority - Second Level

Relationship to Other Studies - If implemented, as determined by the results of studies 1A and 1C, this study would be carried out in conjunction with study 9A on Bird Mortality During Spring Migration. If the results of this study indicate effects such as a blockage inmovement, a study on calving and fall migration of whales (12B) will become necessary.

12B. Effects on Whales During Summer

In July and early August, beluga (whitewhales) move into the warm river waters of Kugmallit Bay and Shallow Bay and remain in these areas until late August. The importance of these areas to beluga is not yet clearly understood (M. Fraker, pers. comm.); calving apparently occurs before the whales actually arrive in these areas. Oil contamination could delay the movement of belugas from the Amundsen Gulf area into the Mackenzie Delta area until the break-up of the ice was almost complete. The significance of such a delay is unknown.

If there is considerable boat traffic associated with clean-up activities, particularly in shallow coastal waters, this could delay the westward migration of beluga and bowheads out of the Beaufort Sea.

Objectives

1) To determine the effects on the movement of belugas into the Mackenzie Delta area that would result from the blocking of their migration routes by oil contamination.

2) To determine the effects of extensive boat activity on the westward migration of belugas and bowheads out of the Beaufort Sea in late summer and early fall.

Methods - This study would require that fixed aerial survey routes be flown systematically and that the positions and numbers of all whales sighted be recorded. It would also require information on the distribution of oil and on the activities of boats in the area.

Timing of Study - Late July to early September.

Criteria for Initiation - This study would be implemented only if

1) the spring migration of whales were to be delayed by oil blocking their normal migration route, or

2) oil contamination were to occur in the access routes used by belugas to reach the Mackenzie Delta area, or

3) extensive boat activity were to occur across the migration routes used by whales to leave the Beaufort Sea in late summer.

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(Contact)

- Dr. A.W. Mansfield, Head

(Project Leader)

- Dr. D.E. Sergeant

Personnel Requirements - This study would require an experienced marine mammal survey biologist to conduct the study, analyze the data, and prepare a report.

Equipment Requirements - tape recorder, tapes, batteries (already available)

Logistic Support

- 155 hr twin-engine fixed-wing aircraft (Cessna 337) with positioning system
- air fare: Montreal-Tuktoyaktuk-return (1)
- accommodation for 2 months at Tuktoyaktuk (1 person)

Funds Required - To prepare: None

To implement:		
	aircraft	$ 35,000
	air fare	1,000
	accommodation	4,000
	TOTAL	$ 40,000

Priority - Second Level

Relationship to Other Studies - The implementation of this study will depend on the results of the Remote Sensing Study (1A) and on the results of the study on Spring Migration of Whales into the Beaufort Sea (12A).

13. Effects of Oil on Human Utilization of Wildlife

Hunting, trapping anf fishing are important activities of the native peoples in the Beaufort Sea area. They provide domestic income (from domestic or subsistence use of wildlife), cash income (from commercial uses), and recreation (Brackel 1977). Wildlife that are the focus of these activities include fish, seals, polar bears, whales, arctic fox and (in the Mackenzie Delta) muskrat.

The utilization of wildlife could be affected by an oil spill in the following three ways:

1) A spill could cause a reduction in the availability of wildlife by causing changes in their numbers and/or distributions. This effect would be reflected in a lowered rate of return per unit of effort expended in hunting, trapping or fishing.

2) Clean-up activities could provide alternative employment and thus reduce the level of effort expended in hunting, trapping or fishing.

3) Spilled oil could reduce the usability of wildlife (e.g. tainting of fish, oiling of furbearers).

The effects of an oil spill on the numbers and distributions of animals have been addressed by other studies in this report. The results of these studies will be important to the interpretation of the following study to monitor the effects of a spill on the utilization of wildlife by the inhabitants of affected areas.

Objectives

1) To assess the effect of a spill on the level of effort expended in hunting, trapping and fishing and on the rate of return per unit of effort.

2) To assess the effect of a spill on the usability of wildlife resources.

Methods - The methods that would be employed in a study such as this have not been defined and would probably vary considerably depending on the size, location, and timing of a spill and on the extent of available baseline information. Accordingly, no attempt has been made to define personnel, equipment, logistical, and funding requirements.

Timing of Study - This study would be carried out for the duration of the spill and would probably be continued on a longer-term basis.

Criteria for Initiation - Any large spill.

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Priority - Second Level

Relationship to Other Studies - The interpretation of this study will be greatly assisted by the results of nearly all the biological studies and particularly by studies 10A, 10B, 10C, 11, 12A and 12B.

LITERATURE CITED

Barry, T.W. 1968. Observations on natural mortality and native use of eider ducks along the Beaufort Sea coast. Can. Field-Nat. 82:140-144.

Barry T.W. 1970. Likely effects of oil in the Canadian Arctic. Mar. Poll. Bull. 1:73-74.

Brackel, W.D. 1977. Socio-economic importance of marine wildlife utilization. Beaufort Sea Technical Report No. 32. Beaufort Sea Project, Department of Fisheries and Environment, Victoria, B.C. 91 p.

Bunch, J.N., and R.C. Harland. 1976. Biodegradation of crude petroleum by the indigenous microbial flora of the Beaufort Sea. Beaufort Sea Technical Report No. 10. Beaufort Sea Project, Department of Fisheries and Environment, Victoria, B.C. 52 p.

Hay, K.G. (ed.). 1976. Guidelines for assessing environmental impact of oil spills. Deliberations of Montauk Workshop, February, 1976. Unpublished Ms.

Herlinveaux, R.H., and B.R. de Lange Boom. 1975. Physical oceanography of the southeastern Beaufort Sea. Beaufort Sea Technical Report No. 18. Beaufort Sea Project, Department of Fisheries and Environment, Victoria, B.C. 97 p.

Kolpack, R.L. (ed.). 1971. Physical, chemical and geological studies. Volume II. In: Biological and Oceanographic Survey of the Santa Barbara Channel Oil Spill 1969--1970. Allan Hancock Foundation, University of Southern California.

LaRoche, G., R. Eisler, and C.M. Tarzwell. 1970. Bioassay procedures for oil and oil dispersant toxicity evaluation. Journal Water Pollution Control Fed., Washington, D.C. 42(11):1982-1989.

Logan, W.J., D.E. Thornton, and S.L. Ross. 1976. A review of oil spill countermeasures. Beaufort Sea Technical Report No. 31. Beaufort Sea Project, Department of Fisheries and Environment, Victoria, B.C.

MacNeill, M.R., and J.F. Garrett. 1975. Open water surface currents. Beaufort Sea Technical Report No. 17. Beaufort Sea Project, Department of Fisheries and Environment, Victoria, B.C. 113 p.

Mattson, J.S., and E.I. Chan. 1976. Report on NOAA-USCG oil spill trajectory effort at Key Largo, Florida, 20-22 May 1976. Environmental Data Service, National Oceanic and Atmospheric Administration, 3300 Whitehaven Street N.W., Washington, D.C. Unpublished Ms.

Milne, A.R., and B.D. Smiley. 1976. Offshore drilling for oil in the Beaufort Sea: a preliminary environmental assessment. Beaufort Sea Technical Report No. 39. Beaufort Sea Project, Department of Fisheries and Environment, Victoria, B.C. 43 p.

NORCOR Engineering and Research Ltd. 1975. The interaction of crude oil with Arctic sea ice. Beaufort Sea Technical Report No. 27. Beaufort Sea Project, Department of Fisheries and Environment, Victoria, B.C. 145 p.

O'Rourke, C. 1977. Oil spill clean-up in the Beaufort Sea. Spill Technology Newsletter 1(6):12-36.

Percy, J.A., and T.C. Mullin. 1975. Effects of crude oils on Arctic marine invertebrates. Beaufort Sea Technical Report No. 11. Beaufort Sea Project, Department of Fisheries and Environment, Victoria, B.C. 167 p.

Richardson, W.J., M.R. Morrell, and S.R. Johnson. 1975. Bird migration along the Beaufort Sea coast: Radar and visual observations in 1975. Beaufort Sea Technical Report No. 3c. Beaufort Sea Project, Department of Fisheries and Environment, Victoria, B.C. 131 p.

Scott, B.F. 1975. Investigations of the weathering of a selected crude oil in a cold environment, p. 514-525. In: Water Quality Parameters. ASTM STP 573. American Society for Testing and Materials, Philadelphia, Pa.

Searing, G.F., E. Kuyt, W.J. Richardson, and T.W. Barry. 1975. Seabirds of the southeastern Beaufort Sea: aircraft and ground observations in 1972 and 1974. Beaufort Sea Technical Report No. 3b. Beaufort Sea Project, Department of Fisheries and Environment, Victoria, B.C. 257 p.

Smith, T.G., and J.R. Geraci. 1975. Effect of contact and ingestion of crude oil on ringed seals. Beaufort Sea Technical Report No. 5, Beaufort Sea Project, Department of Fisheries and Environment, Victoria, B.C. 66 p.

Stirling, I., D. Andriashek, P. Latour, and W. Calvert. 1975a. Distribution and abundance of polar bears in the eastern Beaufort Sea. Beaufort Sea Technical Report No. 2. Beaufort Sea Project, Department of Fisheries and Environment, Victoria, B.C. 59 p.

Stirling, I., R. Archibald, and D. DeMaster. 1975b. Distribution and abundance of seals in the eastern Beaufort Sea. Beaufort Sea Technical Report No. 1. Beaufort Sea Project, Department of Fisheries and Environment, Victoria, B.C. 58 p.

Topham, D.R. 1975. Hydrodynamics of an oilwell blowout. Beaufort Sea Technical Report No. 33. Beaufort Sea Project, Department of Fisheries and Environment, Victoria, B.C. 52 p.

Wong, C.S., W.J. Cretney, R.W. Macdonald and P. Christensen. 1976. Hydrocarbon levels in the marine environment of the southern Beaufort Sea. Beaufort Sea Technical Report No. 38. Beaufort Sea Project, Department of Fisheries and Environment, Victoria, B.C. 113 p.

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